The Principles of Fitting

J. G. Horner

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FOR ENGINEERS, APPRENTICES, AND STUDENTS IN TECHNICAL SCHOOLS

BY

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PREFACE

THE substance of this volume appeared originally in "The English Mechanic" as a series of articles. Some slight re-arrangement and division into chapters have now been effected, and useful additions of notes, facts and tables, which are specially serviceable in the workshop, have been made, and a page on Whitworth Scholarships has been added.

No volume, that I am aware of, has yet been written upon the subject of Fitting. Neither is it possible to treat the subject exhaustively in the space of a single volume, or of a series of articles. I have therefore endeavoured to put myself in the position of a student and apprentice, directing my attention only to those cardinal matters which lie at the basis of the trade, in preference to entering into a multitude of details which would only be applicable to the practice of a limited class of shops. I have also assumed that my readers are thrown upon their own resources without the aid of the automatic machines of our modern shops, and have therefore devoted considerable space to vice work.

There are many matters which I have been unable to include. But they belong, not to elementary, but to advanced practice. I allude to such work as setting valve gears of various types, indicating engines, making

tests of motors and mechanisms. These could not be included to any useful extent in such a volume as this. There are also matters connected with design and the strength of materials to which I have made no reference, because, though embodied in the work of the fitter, he has nothing to do with these in the shops. All these are embodied in the drawings to which he has to work. Such elementary and rough and ready rules as it is desirable that fitters, and especially jobbing fitters, should know, I have placed in the last chapter for convenient reference.

With regard to the ability of the author to undertake this task, I need only remark that Fitting is one branch of that extensive practice of Engineering to which the whole of my life has been devoted.

J. H.

PREFACE TO FOURTH EDITION

OPPORTUNITY has been taken to enlarge and revise this work for the present edition. Considerable alterations and additions have been made. A hundred new illustrations have been added, and eight photo. plates of shop interiors, and the volume is now enlarged by over a hundred pages. New blocks have been substituted for several of the old ones. It is hoped that these improvements will justify the anticipation that the steady sale of the past will be maintained.

JOSEPH HORNER.

Bath.

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THE PRINCIPLES OF FITTING

CHAPTER I

INTRODUCTION

Engine-fitting is the term by which this branch of engineering is usually denoted. It is preferable, however, to employ the title of this work, because the prefix "engine" might convey the impression that fitters have to do only or chiefly with the construction of engines—a too narrow assumption. The range of their tasks is as wide as the general practice of engineering itself, and although there are numbers of men who are trained in, or who fall into special grooves of work, the general practice, and not special exceptions of the trade, must be considered in the chapters to follow.

In this introductory chapter an answer may be given to two questions: "What is fitting?" "How is the fitter trained?"

Fitting, in its broadest sense, signifies the union of the various portions of which a mechanism is composed. But it embraces more or less of the preliminary preparation of parts, as well as their subsequent union. It also includes the repair and reconstruction of all classes of engineers' work. It deals with the smallest and most delicate

machines and models, and the largest and most powerful engines, cranes, and pumps, and all the thousand and one forms in which mechanism occurs. It embraces the manipulation of all the common metals and alloys, together with a practical knowledge of their properties and special uses; a rough and ready knowledge of approximate strengths of ropes and chains, beams and elements; a sound idea of the best methods of slinging and hoisting heavy castings, forgings, and parts of machinery; and a good working grasp of the nature, and properties, and behaviour of water, steam, gas, and air. The practice of the trade presupposes good physical health, able to stand the extremes of outdoor winter temperature, the scorching heat of summer, and the close atmosphere of boiler sheds and stoke-holds, for a jobbing fitter never knows where he may be sent to work at an hour's notice. In short, the fitter stands as the visible embodiment of the engineer. The work of the draughtsman, the pattern-maker, the boiler-maker, smith, and turner is of a sectional character. Not until prepared parts come into the fitter's hands does a mechanism assume complete and imposing form.

Year by year the tendency has been to cheapen and reduce the work of the fitter. Vastly more shaping and finishing is done by machines, instead of by chisel, file, and scrape; so reducing the fitter very often to little more than a mere mechanical assembler, or erector, who brings the parts together. Hence good general hands are not so easily obtainable as formerly. This is an evil common to many other occupations besides. It, however, affords a reason why young men should strive hard to qualify themselves as good all-round hands, rather than as mere specialists.

Training.—Fitters are usually trained by spending five

or seven years in a workshop, either as apprentices or as non-indentured lads. But what kind of men they will become depends on the class of shop, and—themselves. Time is almost absolutely wasted in a specialized shop where only one class of work is done. It is bad for a lad to be everlastingly doing one task. Yet this is what falls to his luck in many shops. Parents should eschew the big firms with a name, and put their lads in the roughest little general country shops, if they want them to gather a general knowledge of the trade. In these places they will have to turn their hands to all kinds of miscellaneous tasks—the best training which lads can have. It does not matter if they remain ignorant of many modern machine processes; if they are unacquainted with the latest modern labour-saving machines; if they miss the routine work of the big factories. All this will be gathered by and by. But they will acquire in the early years of life that which is of immensely greater value—they will become skilful with chisel and file, perhaps at lathe and forge, quick at scheming dodges, and ready at hurried repairs, and generally conversant with engines of various kinds, pumps, and mill-work, machines, many and various, antiquated and modern. That country training will be better than many books, and it will leave ineffaceable impressions gathered during the most impressionable period of life. It is desirable to supplement this with attendance at the evening classes of technical schools, and to read the periodical technical press. Abundant opportunities of these kinds now exist for self-culture. No one can afford to neglect these who desires to occupy an ultimate position of responsibility.

After such training, a lad can become almost what he chooses. With power to move from shop to shop—eyes

open and hands alert—the result will be that in a very few years no task will come amiss to him.

Prospects of the trade.—The average of fitters' wages is about the same as that of the other branches of engineering. According to district, they will range from 30*s.* to £2. But a fitter has, I think, better chances in life on the whole than others. A large proportion of the men work by the piece, and so increase their earnings. They are in frequent demand on foreign stations and railways and public works, where they secure high wages, that, if husbanded for a few years, are sufficient to render them independent for life. Many works managers have begun life as fitters. As trades go, therefore, fitting is one of the best—at least, for the man whose training has been that of a general shop, and not that of a special shop or department.

It is regrettable that many young men with energy, and college training, should spend many fruitless years in the hope of gaining some appointment worth perhaps no more than from £2 to £4 a week. To think that after seven or eight or ten years of preparation, young men should be *waiting* in eager expectation—waiting with heart-sickening deferred hope for an "appointment," struggling among scores or hundreds of applicants for their one poor chance of engagement! To such I would say: "Strike out in another line, qualify yourselves as working-fitters. You can always get bread and cheese at that if you give as much energy to it as you give to the theoretical side of the business." A good fitter need never be long out of a job. Employers want him quite as much as he needs them.

No written articles can teach fitters' work. But what aid can be afforded by written description I hope to give.

Having been much among this work throughout my life, I propose to jot down those matters which are of the most fundamental, elementary, and important character. And I shall suppose readers for the most part to consist of apprentices, and of those improvers who have lacked the best training of the shops.

CHAPTER II

TOOLS—CHISELS, HAMMERS, FILES, SCRAPES

THE tools and appliances used by fitters working only at the bench are not numerous, if compared with those required by wood-workers. But if we include those employed by jobbing fitters and out-door erectors, a large quantity are wanted. For the latter require all kinds of tackle, massive and otherwise. Some of these are treated in other chapters. The remarks in this relate only to the principal tools used upon the work-bench. These embrace various chisels, hammers, files, scrapes, scribers and scribing-blocks, calipers and compasses, rules, squares, trammels, drifts, spanners, broaches or reamers, screwing tackle, surface-plates, etc.

The chisel group.—In this we have the common chipping-chisel, Fig. 1; the key-way, cape, or cross-cut chisel, Fig. 2; the sett, diamond-point, or cutting-off chisel, Fig. 3; the round-nose, or oil-groove chisel, Fig. 4; and the gouge, or cow-mouth chisel, Fig. 5. Each of these occurs in various sizes, and the cutting-angles of each are also slightly varied, in order to adapt them for the various classes of metal and alloy upon which they have to operate. Average angles taken from chisels in use, picked up at random from the benches, are indicated by dotted lines. As the sketches are scaled fairly like the originals, they may be taken to represent good proportions, though pro-

portions vary, both in length and sections. Sometimes a round or oval rod is used for the narrower and smaller

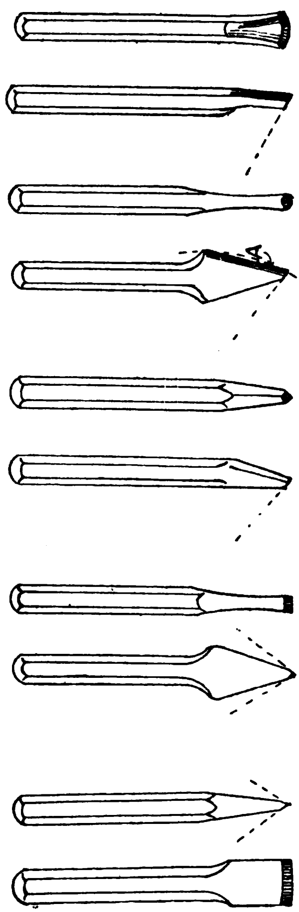


FIG. 1 Chipping-Chisel.

FIG. 2 Cross-Cut Chisel.

FIG. 3 Cutting-off Chisel.

FIG. 4 Round-Nose Chisel.

FIG. 5 Cow-Mouth Chisel.

tools, but, as a rule, the cross section is octagonal. They are tempered from a straw, inclining to a purple or violet

colour, of lighter or darker shade, according to the quality of steel used, and the nature of the work they have to do.

With regard to their general functions, Fig. 1 is used in various widths for cutting any surfaces, broad or narrow, preparatory to filing. The width ranges from about $\frac{1}{2}$ in. to $1\frac{1}{4}$ in. Fig. 2 is, as its name implies, employed for recessing any narrow grooves with flat bottoms, such as key-ways in shafts, and in wheels, when such is done by hand, which happens only, or chiefly, in outdoor work and in small workshops, or at home by amateurs. Its width may range from $\frac{1}{16}$ in. to $\frac{3}{8}$ in. As a cross-cut it is in much request, reducing the labour and risk of chipping large surfaces entirely with Fig. 1. By running a number of narrow and shallow grooves with this chisel from edge to edge across a large area in straight and level lines, the work of the large chisel is divided into sections, each of which is operated on more readily, quickly, and safely than the entire area taken at once would be. Fig. 3 is used for running a groove across a thin piece of plate in order to enable it to be fractured easily, or around a piece of pipe for the same purpose. Fig. 4 is employed for cutting the narrow oil channels in shafts, and on flat machine slides, and in the bores of loosely-running wheels and in brass bearings. In the latter cases, and for operating on concave surfaces in general, the back of the chisel is made convex, as shown by the dotted line at A. From $\frac{1}{8}$ in to $\frac{1}{4}$ in. or $\frac{5}{16}$ in. is the width of an oil groove chisel. Fig. 5 is used for cutting away projecting lumps from the interior of cored holes, and from hollow, curved surfaces. It is made from about $\frac{1}{2}$ in. to 1 in. wide, and in various curvatures, like wood-workers' gouges. These are the typical uses of these tools, but their practical service is very manifold.

Chisel-making.—There is not very much involved in making and tempering the various chisels, but a little practical experience, soon gathered, is necessary.

The art of forging these plain tools consists in hammering them down to shape from rods of suitable section, which is kept in stock for the purpose. It is simply a case of tapering down under the hammer; there is no upsetting or welding, or really difficult work about it. The real art lies in the observance of two cardinal matters —viz. the heat suitable for forging, and the heat, as indicated by colour, suitable for tempering.

There are two extremes of temperature equally injurious to tool steel. One is a white heat, at which the steel becomes burnt, the other is the black or "blue" heat, at which, if hammered, it becomes very much weakened. The range of temperature for forging, therefore, lies between a red, or full red, or blood-red, and that at which the last faint tints of red disappear. Physics to restore steel that has been burnt by overheating are not used to any important extent in the shops. If a tool becomes burnt—a not very unfrequent occurrence—the burnt end is just knocked off and thrown away, and the tool is reheated and reforged.

In reference to the heat for tempering, some difference exists, depending partly upon the character of any given bar of steel, and partly upon the nature of the work that has to be done by the tool. Colours range from a straw to a purple for most of the tools. The first is that for cutting the hardest materials, the last for tools of softer temper.

Tempering.—The precise method of tempering chisels, drills, and similar tools is this: The tool is first placed in a clear fire, the blast put on sparingly to raise the

temperature gradually and evenly, until the tool becomes of equal temperature throughout. This is important, because if the outside is heated too suddenly the interior will remain comparatively cool, and the effect of plunging it into water in that condition will be to crack it, by reason of the unequal shrinkages of the exterior and interior unequally heated layers. When heated to a blood red, or a dull red, the tool-point for a length of 2 in. or 3 in. is plunged vertically into the water-bosh and moved slightly up and down in it until quite cold. The point is then, of course, intensely hard. One face of the hardened portion is then quickly polished with a bit of a broken grindstone or emery-wheel, and the finger or a bit of waste brushed over it. By that time the heat left in the unhardened portion of the tool has begun to sensibly communicate itself to the hardened portion. The tints of oxidation begin with the light straw, and so pass through successive tints into deep purple. It is not easy to describe tints by name, as different smiths will call the same colours by different names; and tint, moreover, depends on the nature of the light in which it is observed. Light straw, deep straw, yellow, plum-colour, purple, purplish straw, and so on, are more or less confusing. The best way is to watch a tool-smith at work, and then imitate his methods. Still broadly, in the average light of the shops in daytime, we may say that chisels for steel and cast iron should be quenched for tempering at a straw, lighter for hard iron, darker for soft ; for wrought iron and brass, the straw should have merged into a faint purple, not a deep purple, or the tools will be of spring temper. When the tool is to be finally quenched for tempering, it is immersed vertically, and moved up and down in the water until quite cold.

Drills.—As a rule, the common flat drill is that used most by fitters. The twist drills are not used to so great an extent as they are at the machines. A greater variety of drills are employed in lathes and machines than at the bench. The flat drill and the ratchet brace are almost exclusively used in work done at the bench.

Flat drills are easily forged by hammering them down from a suitable bar, and cutting the bevels of the lips with a hot sett, leaving the finish to be imparted at the grindstone. They are first hardened like chisels, then tempered at a dark straw in the same way as chisels.

Hammers.—Typical fitters' bench hammers are shown in Figs. 6, 7, and 8. Their differences mainly consist in the

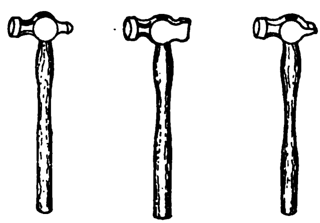


FIG. 6	FIG. 7	FIG. 8
Ball Pane Hammer.	Straight Pane Hammer.	Cross Pane Hammer.

form of the pane—as the ball pane, Fig. 6; the straight pane, Fig. 7; and the cross pane, Fig. 8; all having their several uses at various times. Fitters' bench hammers weigh, as a rule, about 1½ lb. each. The round pane is in most general use. The special value of the round form consists in the ease with which riveting can be commenced;

a few blows from the round pane on the centre of a rivet spreading out the metal at once. The cross pane is valuable for finishing a rivet round the edges. The straight pane is serviceable for working in a narrow space. Each

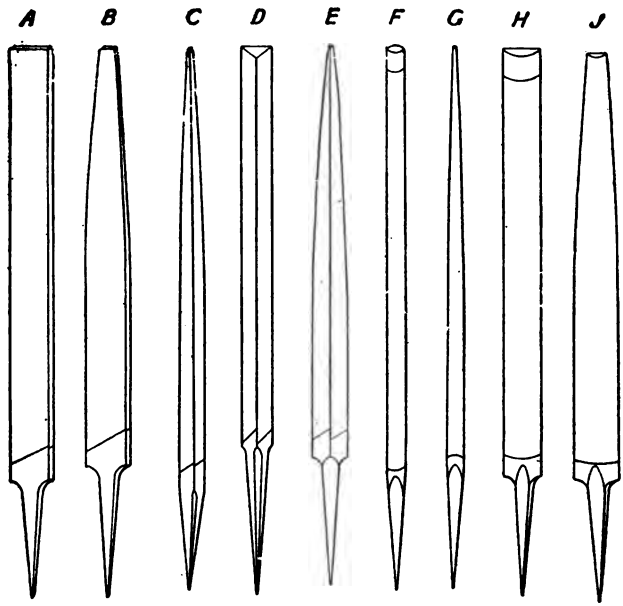


Fig. 9

Longitudinal forms of Files.

form of pane in turn is serviceable for levelling sheet-metal by hammering.

Hammers of lead, copper, and raw hide are used for driving articles which have been tooled bright, and the faces of which would be damaged by blows from a steel hammer. Those of lead and raw hide are handled like

ordinary steel hammers, but have flat faces. Those of copper are generally encircled with wire, and interposed between the object struck and a steel hammer by which the blows are delivered.

Files.—These are most important tools—a large assortment of which is desirable. Nearly all files are sold in various degrees of coarseness of cut—*rough, bastard, second cut, smooth,* and *dead smooth.* Lengths vary also. The rough, bastard, and smooth qualities, however, of one

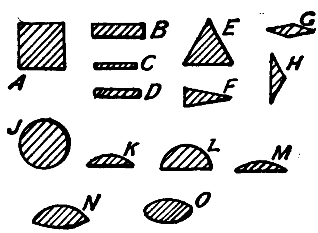


FIG. 10

Sections of Files.

class of file do not correspond with those of another class; but a small file has finer teeth than a large file, even though of the same name. Then they are further distinguished (Fig. 9) as *parallel, blunt* or *blunt-pointed* (A, D, F, H); and *taper* (B, C, E, G, J). B and J are also called *bellied* files. The taper files diminish in sectional area from tang to point; not strictly so, however, because they are bellied or enlarged about the middle. A blunt-pointed file is almost, though not quite, parallel throughout its length. *A dead parallel* file is practically parallel. In fitters' work, the blunt and parallel files are chiefly used; the bellied

types being only employed for the roughest class of work. Also, files are *single-* and *double*-cut—that is, they have one set of cuts only, or two crossing sets. Fitters' files are always double-cut, not single.

The forms of files used vary with the class of work mostly done; but, speaking generally, those employed by fitters are of commoner forms, and not of unusual sections. The files used chiefly are those of rectangular section, of triangular section, and of various curved sections.

The commoner sections used are grouped in Fig. 10. A large proportion of them can be had in lengths of from 3 in. or 4 in. up to 24 in., and in most of the grades of coarseness just now mentioned; and those of rectangular section are obtainable with one edge smooth (*safe edges*). For the average work of the fitter, the most useful lengths for average files would be about 10 in. or 12 in., less for smaller types, more for larger, coarser types.

In Fig. 10, A is the square file (C in Fig 9), B is the hand file, or flat file. Cottar files are of smaller sections, as B, but they are narrower in proportion to thickness than the figure. Taper cottar files, or entering files, are of similar section; but, unlike the flat and cottar files, they are tapered and bellied.

Equalling files, C, are very thin, and usually parallel in both thickness and width. Sometimes the edges only of these files are cut, both the flat faces being left smooth. When tapered, these files are called slitting and warding, and for specially fine fitting they are of much service. Pillar files come midway in proportion between the cottar and the equalling files. Hand and equalling files are sometimes provided with rounding edges, like D, for filing cottar-ways, which is the section of mill-saw files.

The triangular file, E, Fig. 10, and D, E, Fig. 9, is more valuable than forms F, G, H, which have a rather limited value. F is the knife-file, G the feather-edged, and H the cant file. As their sections show, they are valuable for filing into angles.

The group beginning with J is highly serviceable. J is the common round file (F in Fig. 9) or, when tapered lengthwise, G, Fig. 9, the rat-tail. K is the half-round, J in Fig 9—a misnomer, because it does not form a hemi-

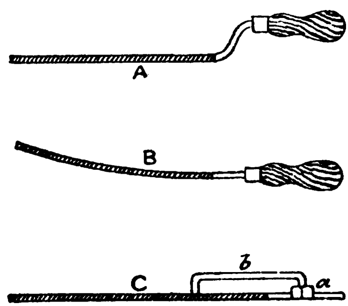


FIG. 11

Modes of Handling and Bending Files.

sphere. The true half-round, L (H in Fig. 9), is called a high-back half-round, or a pit- or frame-saw file, and is parallel, while K is always bellied. M, being thinner than K, is a flat-back half-round or cabinet. The double half-round N, or crossing or tumbler file, having unequal curvatures on opposite sides, is not very much used by fitters. Neither is the oval file O.

It is not easy, when work differs so much, to say which files in group 10 are of most service. But, speaking in a general way, those chiefly in use are A, B, C, D, E, J, K, L.

We may consider each of these in several grades as quite indispensable.

File handles.—These should always be globular at the heel portion, which lies in the hollow of the hand. If made oval, or more or less pointed, the hand soon becomes sore and fatigued.

When the tangs of files have to be bent, Fig. 11, A, for operating on broad, flat surfaces, the teeth must be protected from heat by placing the body of the file between two thick pieces of iron, and enclosing the whole in the damp slack of a smith's fire, thrusting the tang only into the clear part. When the cutting part of a file has to be curved for operating on concave work, B, it is heated to a blood-red, and hollowed with mallet-blows on a block of wood cut to the required curvature. It is tempered by reheating to a blood-red and quenching in water or oil.

A common method of handling a file for operating on large flat surfaces without bending the tang is shown at C. Here *a* is a nut filed out to fit over the tapered tang, upon which it is driven tightly; *b* is a bit of $\frac{3}{8}$ in. rod, bent round at each end. One end is tapped into the nut, the other rests upon the file; *b* forms the handle, therefore, the nut holds it very firmly.

The scrapes.—These occur in two forms—those of triangular section, and those of oblong section. They are frequently made of worn files ground smooth, and sharpened upon an oilstone. The scrape shown at A, Fig. 12, is employed for flat surfaces, and is, when inclined at an angle with the work, operated lengthwise. B is used for working in overhanging vees. The form C is used for smoothing concave surfaces. If a file is used, it is ground smooth for a length of about 2 in. only, and being rubbed

on an oilstone becomes very keen; while the large angles formed between the faces permit of the preservation of

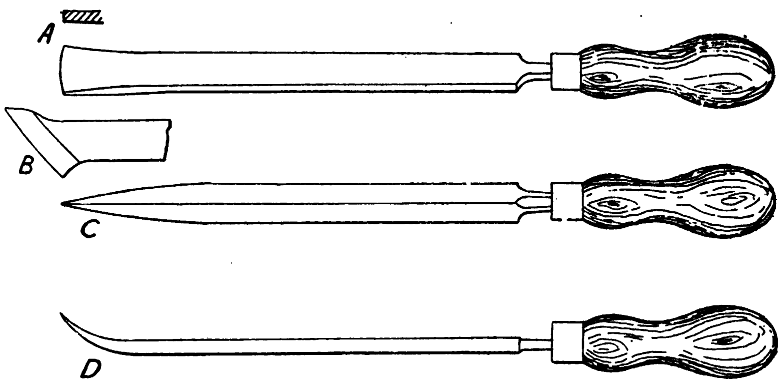


FIG. 12.
Scrapes.

the edge for a good while. The tool C is worked transversely to the length, and is, therefore, employed for concave surfaces, journal bearings, and such-like.

CHAPTER III

TOOLS (*continued*)—SCREWING-TACKLE

THE problems of mechanical power, strength, and durability which determine the forms of screw-threads, and the history of the evolution and ultimate selection of the standard Whitworth threads, can be read in text books. Here we consider screw-threads from the standpoint of the workman, whose aim is to give practical effect to the principles which have long been laid down and settled. It depends upon the skill of the workman, and the class of tools he makes and employs, whether the screw-threads be keen, sharp, and smooth, or rough and jagged; whether time is lost, or economized, and whether fitting is good or bad.

Taps and dies.—Every one knows that there are great differences in the manner of operation of different sets of screwing-tackle, less when the tackle has been bought of approved makers than when it has been made by different men in jobbing-shops; for there are, and always have been, tools made in such shops; though the tendency is to purchase more articles of those kinds which are specialities. Thus many firms, most small ones, in fact, not only buy all their screwing-tackle, but also their bolts, washers, and nuts, and their keys, brass fittings, emery wheels, cutters, rivets, and many other things. But screwing-tackle is expensive, and while, therefore, a few sets will be bought,

the practice still is, in some of the smallest firms, to make a large number of taps and dies for their own use.

It not infrequently happens that good workmen have somewhat crude ideas as to the correct principles of tool formation; and working in a tentative fashion, they do not always get the very best results. There are few tools in which very slight, very minute departures from correct form, will so greatly increase the labour of working them as screwing-tools. One sometimes see taps so large as $\frac{1}{4}$ in. or $\frac{3}{8}$ in. with flat instead of fluted cutting edges, or taps with edges not grooved-out sufficiently to cut freely, or taps retained in use long after all their original keenness of edge has been worn off, and taps chipped and damaged, or dies cut over hobs of unsuitable diameter, and so on. A few remarks on the correct formation of common screwing-tackle may, therefore, be of value.

Hand-working taps are made three in a set (Fig. 13): the taper or entering, A; the middle or second, B; and the plug or bottoming, C; with each set of working taps a plug, master, or hob tap is also included.

The entering tap A is tapered from the point to the sixth thread from the top. The diameter *a* at the point is the diameter of the bottom of the thread. This tap, as its name implies, is used for commencing the thread in a drilled hole. The second tap B is tapered from the point to the sixth thread from the point. Its diameter at the point is also equal to that of the root of the thread. This is used for continuing and deepening a thread commenced with A. In the plug tap C there is no taper whatever, and its purpose is the finishing of threads down to the bottom of a blank hole. The entering and the second taps are backed off, or relieved throughout their entire length; the plug tap is also backed off; the actual cutting is done

chiefly with A and B, C only finishing the bottom of the thread, and smoothing the remainder. The master tap, Fig. 14, is not tapered, but is backed off. Its diameter is also greater by twice the depth of the thread than that of the working taps, and the number of flutes or grooves is greater. The reason for this will be apparent directly.

The object in *backing off* is to afford an angle of relief,

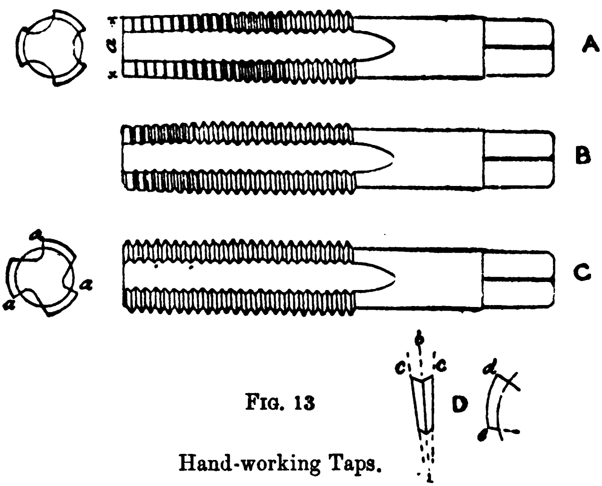


Fig. 13

Hand-working Taps.

or clearance to the cutting-edges, of the same nature as that imparted to turning and other cutting tools. Formerly this was imparted by the file after the taps were screwed, but before hardening. The effect was similar to that shown in an exaggerated diagram in Fig. 13, D. If *b* is the point of the thread, its flanks are filed to the angles *c c*, and this has the effect of making the radius of the leading edge *d* greater than that of the leaving edge *e*, and the whole of the sectional area of the tap thread

diminishes from *d* to *e*. Though very slight in amount, the backing off has the desired effect of relieving the tap from the stress of excessive friction. But now taps are backed-off in a similar fashion to milling cutters.

Dies.—These are cut in the solid screw-stock or screw-plate for very small threads. In all sizes above about $\frac{3}{16}$ in. diameter they are made movable, and contained in stocks of suitable forms, two, or else three dies being embraced in a stock. In general workshop practice the

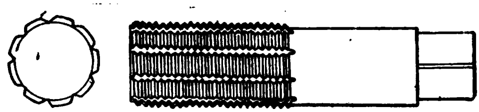


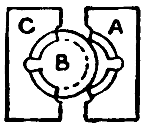
FIG. 14
Master Tap.

two-die stocks are mostly used. Those with three dies are, however, superior in all respects.

Dies are cut on the master tap (Fig. 14) just now mentioned, and the reason why this tap is larger by the depth of two threads than the diameter of the working taps will be evident if we consider the action of the dies when cutting.

When a screw-thread has to be cut by means of dies, the screw-blank is of the same diameter as the points of the threads. If the dies were of the same precise curvature as the screw-threads, that is, if they were cut on a hob of the same diameter as the screw-threads, this would happen: On first commencing to operate, the extreme corners only of the dies, Fig. 15, A, would scratch a screw-thread on the outside of the blank B, the angle of which thread would differ considerably from that of the ultimate screw point, and, further, the guidance of the

dies would be very imperfect. By the time the thread was finished, the curvatures of the dies and of the thread would be precisely alike, C, and no more cutting action could possibly take place. So that if the thread made too tight a fit with its tapped hole, it would be impossible to reduce it ever so slightly. When these dies became



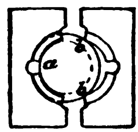


FIG. 15 FIG. 16

Method of Operation of Dies.

worn blunt, it would be impossible even to cut a thread quite down to its correct size. Moreover, as the angle of the thread being cut would be continually altering as the thread was deepened, a deal of friction would be developed during the operation.

But when dies are cut upon a master tap larger in

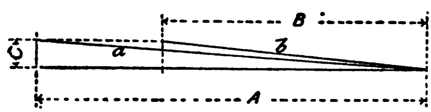


FIG. 17

Diagram to Illustrate Angles of Screw Threads.

diameter than their thread, the effect is this: In the first place, Fig. 16, the curvature of the smaller diameter of the tap and of the outside of the blank are not so dissimilar as they were in the previous supposition. There is, therefore, somewhat better guidance. Then the difference in angle is lessened. And when the screw has been cut to its correct diameter, the curvatures of the dies and of the thread are still unlike, and the inner

edges *a* will cut the thread smaller, if so required, to make an easy fit with the tapped hole.

Dies, therefore, properly formed, that is, over a master tap of two threads larger, when operating, cut first upon the outside corners *b*, Fig. 16, until the thread is nearly

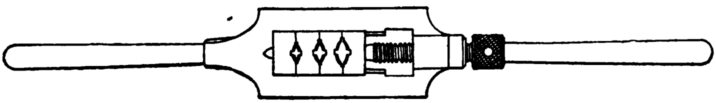


FIG. 18
Die Stock.

completed, when the inner corners *a* begin to cut, and continue to do so until the thread is finished.

Fig. 17 will make the reason of difference in angle at root and point clear. If the length A represents the circumference of the point of a screw, and the length B the circumference of its root, and C the pitch, then *a* will

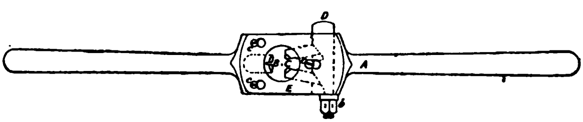


FIG. 19
Guide Screw Stock.

be the angle or slope of the point, and *b* the slope of the root. In dies cut over a hob two threads deeper than standard, the angle *a* will be that first traced on the blank. In dies cut over a hob of the same size as standard, the angle *b* will be that first traced, which will be gradually changed to the angle *a*.

Die Stocks.—Fig. 18 illustrates one form of die stock used for the dies shown in Figs. 15 and 16. It has the

pinching-screw combined with one handle. In the "angular" pattern both handles are solid with the body, and the screw is set at an angle. The dies may be in one pair, or multiple, as in Fig. 18. In Figs. 19 and 20 a better type is shown. It is

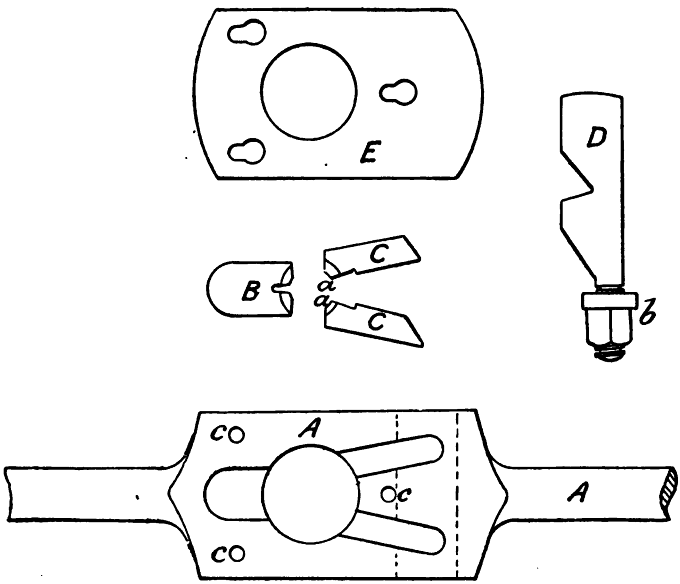


FIG. 20
Guide Screw Stock—Enlarged.

called the Whitworth, or "*guide screw stock*," and its dies are of different construction from those in Figs. 15 and 16. Fig. 19 illustrates the general appearance of the stock. Fig. 20 shows the operating parts enlarged. In the figures, A is the body of the stock, provided with three grooves, in which slide the guide B, which does not cut, and the actual cutting-dies C C.

These cut by their inner edges, *a a*, and are thrust forward to their work by means of the wedge D, tightened up with the nut *b*. The dies are kept in place with the plate E, screwed upon the body of the stock. The screws *c c c* always remain in place, and the plate E is slotted to slip along them. The guidance of this stock with B in place is excellent, while the narrowness of the cutting-edges of C C diminish the friction due to alteration of angle. These are cut over hobs two threads deeper than their taps.

Fluting and grooving.—With reference to the forms both of taps and dies most suitable for cutting freely, some difference exists in practice. Of course, the old style of grinding three or four flats on taps to form cutting edges has long since been discarded, except in the case of very small ones of $\frac{3}{16}$ in. or less in diameter. In all taps of larger sizes than those, grooves or flutes are cut, and in this way, assisted by the backing off, serviceable cutting edges are obtained. There or two or three ways of cutting these grooves; Fig. 13 shows the best methods.

Fig. 13, A, is very common, but it is being superseded by C; the latter is stronger by comparison than the former; it has a more perfect cutting angle, the cutting edges *a* being radial past the bottom of the screw-thread, while in A the cutting edge turns off into a sharp curve at the root of the thread, and makes the cutting angle slightly obtuse instead of at 90°. There is also quite as much room in C for holding the chips or swarf as there is in A; therefore it embodies the best form of flute in use.

In Figs. 15 and 16 the best form of groove for dies is shown. These are radial. Not infrequently they are filed out parallel with a parallel file; but it is better to make them as in the figure. In the case both of taps and dies, cutting or squeezing action predominates, according

as the cutting edges are radial or not, and according to the sharpness or smoothness of those edges. We cannot get a sharper angle than that afforded by a radial disposition of the edges, without weakening the leading corners, and making them liable to crumble off. But neither should we have a more obtuse angle if we want to economize labour and cut sharp threads. Nor should taps or dies be used after their edges are dulled without regrinding them.

Die-nuts are employed for running down studs, or other screws which have become damaged, so that their nuts will not go on. The dies are hexagon, Fig. 21, or square, Fig. 22, so that they can be readily rotated with a spanner.

Tap-making.—In most workshops there is a tool-smith, whose special work is the making and tempering of the tools used by the turners, machinists, and fitters. Yet a fitter may frequently be so circumstanced as to find himself very awkwardly placed if unable to make and temper a special form of tool; so that it is highly desirable that all fitters should, on occasion, be independent of the tool-smith. In general country shops there is scarcely a man who cannot do jobs of this kind for himself. Lads trained in very large establishments, however, have no chance to learn such work, nor even to grind their own tools. These are simply handed round ready for use, and taken away again when out of order.

Crucible steel is the best for taps. The blanks are cut off from the rod and forged to outline. They are then annealed, by slow heating to a cherry-red, and slow cooling in the ashes of the forge. This process softens them, and relieves the steel of any internal stresses that might cause curving during hardening. They are next centred, and

rough-turned in the lathe, and carefully examined in order to ascertain the presence or otherwise of seams in the metal. If found all right, the turning is completed, and the square head is machined or filed. Finally, the threads are cut, but slightly bare to required size, as the process of hardening expands them.

The grooving follows. This is done in wholesale manufacture in special machines; but it can also be done in any lathe with a circular mill of suitable section set

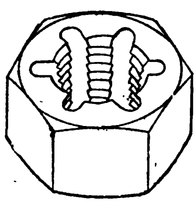


FIG. 21

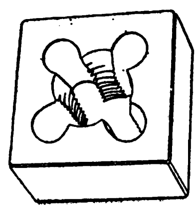


FIG. 22

Die-Nuts.

running between centres, the tap passing underneath it in a suitable fixing on the slide-rest; or the tap can be set between centres, and the mill be driven from overhead. Or it can be done more clumsily with a cutting-tool in the shaping machine. The small taps may be done by filing. After the grooving, the backing-off, illustrated on page 20, is done with a file, or in a relieving lathe.

When taps are manufactured in quantity they are heated in special furnaces. When they are hardened and tempered in the jobbing workshop they are heated in the fire within a hollow piece of gas or steam-tube. The tube must be large enough to permit of the entrance of the tongs which hold the tap. It is placed in a sloping

position in the fire, and the tap is slowly rotated when it is getting hot, in order to prevent risk of its bending, which it would do if left in one position. Its temperature must be raised slowly to heat it uniformly, and a dull red heat must not be exceeded. Then it is plunged vertically into lukewarm water and held there until quite cooled down to the temperature of the water. These points are of great importance—the uniformity of temperature throughout, the vertical direction when plunging, the keeping in the water till cold. Neglect of these will cause fracture and curvature.

Next polish one groove, with a buff or with a piece of stone or of broken emery-wheel, in order to have a bright surface on which to observe the tints.

To temper, hold the tap in the red-hot iron ring until a light straw colour or golden yellow appears, and then plunge into water. It is better when heating for tempering to make the tube white hot and remove it from the fire previous to the insertion of the tap. The changing tints will then be more readily observed than if the tube were left in the glare of the fire. If the tube is thick it will retain heat sufficiently long for the purpose required.

The square necks are better if tempered at a blue heat, as they are then less liable to fracture.

Special mixtures for tempering are not used to any great extent by the jobbing engineer's tool-smith. Water, with or without salt, and water that is seldom changed, but used over and over again, is chiefly employed. Sometimes, however, for taps the water is made thick with soap; also, to protect the edges of the threads, the grooves are filled with soap. But neither are essentials.

Die-making.—Dies are somewhat less troublesome to make than taps. The halves are cut from the bar, and

fitted by shaping or filing into their stocks, their thickness being in excess of the finished thickness. A liner is then fitted and inserted in the stock between the die blanks, its thickness being equal to the amount of normal opening allowed between the dies. The three pieces—namely, the two half-blanks and the thickness piece—are then screwed up tightly by means of the adjusting screw of the die-stock, and their top and bottom faces are planed or filed level and parallel. A central hole is then drilled through the three, equal in diameter to the roots of the screw-threads of the master tap that is to be used for screwing the dies. The packing piece is then removed, the blanks opened out, and the threads cut with the master tap. As the threads deepen the dies are gradually screwed up, until the threads are of their full depth. Lastly, the grooves are filed out.

The dies are hardened by immersion in water or oil while at a dull red. They are then polished, and tempered by heating on a hot plate, upon which they are turned over a few times to ensure uniformity of temperature, and quenched at a dark straw.

Screw proportions.—The standard screw thread owes little to theoretical deductions. It is mainly a compromise, a mean adopted from an exhaustive comparison of threads long in use. Whitworth in England, and Sellers in America are the names chiefly associated with the standardizing of screw threads. Both being practical engineers, the labours of both consisted mainly in comparing and averaging the works of their predecessors and contemporaries. In the standard threads now used, to which all screwing-tackle is now made, exact relationships are not necessary. Adaptability of means to ends is the only essential condition. In the abstract, or apart from ex-

tensive previous experience, no theoretical deductions would have been of any value in determining the proportions of standard screw threads. Questions of pitch, of relations of diameters at points and roots of threads, and of thread sections cannot be settled except by long experience. Yet the consensus of experience has resulted in the standardizing of threads which are not very dissimilar in either of these respects. For the conditions which have to be fulfilled are of an opposite and contradictory character. Any one element, if unduly developed, diminishes the strength or efficiency due to other elements. If the angle of the thread is increased too much, stress is thrown upon the nut; if the thread is deepened, the strength of the bolt is weakened. If the threads are made of fine pitch and section to increase holding power, their durability is lessened for wearing purposes. If threads have keen angles they are not only more liable to injury than those with top and bottom angles obliterated, but the tools used in their formation are more difficult to make, especially in the case of the smaller sizes.

The Whitworth thread in England and the Sellers thread in America differ from each other to a slight extent. The latter was proposed by William Sellers, and afterwards recommended for general use by the Franklin Institute in 1864. It is generally known as the United States Standard. It is formed to an angle of 60° instead of 55° as in the Whitworth, one-eighth instead of one-sixth is cut off from top and bottom, and the top and bottom are flat instead of being rounded. There is little to choose between the Whitworth and the Sellers thread. Both are a mean between extremes. Each has desirable points, which the other has not. Little need be said about the difference in the angle of the threads, 55° and 60°. There

is no reason why one should not be as good as the other. The Sellers is, of course, slightly stronger, and the friction due to the increased angle is greater. There is no important difference in pitches, some, in fact, are identical. The difference in depth of the thread, due to the fact that one-sixth is taken off top and bottom of the Whitworth, and one-eighth only of the Sellers, is in favour of the strength of the latter. On the other hand, the flat in the root of the Sellers is more likely to invite fracture than the rounding in the root of the Whitworth. Yet, since bolt threads are always stronger than the cross section of the body of the bolt—in other words, since a bolt will become torn asunder at the roots of the threads before the threads will strip—this is not a real objection. Against the Whitworth root and point it is urged that the exact rounding is more difficult to obtain than a mere flattening of the root and point. There is some basis for this, and in fact it is omitted in the smaller screws, the threads of which are left keen. The interference of points and roots which are not of the exact depth and curvature will prevent exact fitting of the sides of the threads. One of the reasons which induced the Franklin Institute to recommend the angle of 60° was the fact that the angle was one more readily obtainable than any other, and because it was already in existence in America to the exclusion of almost any other.

These, and some of the other principal screw sections, with tables, are given in the Appendix.

CHAPTER IV

KEYS, COTTARS AND PINS, AND CASE-HARDENING

THERE are some elementary parts of machines which are of cardinal importance, the parts, namely, with which structures of all kinds are united. What nails and screws are to the carpenter, bolts and rivets, cottars, keys, and pins are to the fitter. They are all very simple in form, are in constant use, and are often apt to be overlooked or neglected. Yet on their design and method of fitting the stability and accurate working of an entire mechanism often hangs. It is of the first importance, therefore, that the fitter should have a good knowledge of these elementary parts of machines. Though apparently so trivial, they are cardinal parts. It is the old tale, "For want of a nail the shoe was lost," etc. The giving way of a key or a screw, or bolt, or cottar, or pin may cause other parts to slacken, and become a fruitful source of ultimate trouble. Very often these elementary fittings are given to lads to do, and if the foreman does not happen to notice them, they are left slop fits, or otherwise faulty.

Key-fitting.—This operation is one of much importance. Upon the proper fitting of keys in their key-ways depends much of the stability and permanence of wheels upon their shafts. Among the different keys occasionally made use of, there are two employed to a considerable extent in engineers' workshops—the ordinary gib-headed form

and the sunk key, or feather. The saddle key, Fig. 23, depends on friction for its drive, but it is satisfactory in many instances, where the duty is light. It is also handy

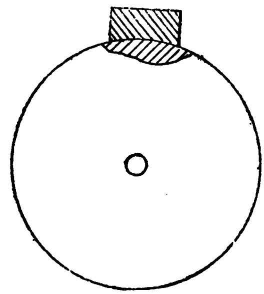


FIG. 23
Saddle Key.

for temporarily keying wheels, etc., on shafts, when it is not desirable to make a keyway until the positions of various parts have been finally settled.

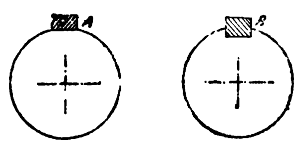


FIG. 24
Keys.

Gib-headed keys.—These are made either to lie upon a flat filed upon the shaft, Fig. 24, A, or to lie within a groove cut into the shaft, Fig. 24, B, and Fig. 25. Except for the very lightest work the latter is invariably adopted. The key-grooves in shaft and wheel are variously made.

In the shaft they are cut with a revolving slot drill or a milling cutter, in the wheel they are cut under a slotting machine, or on a key-seating machine. But though cut with a machine there may be some adjustment—some easing—necessary, and much more so when they are cut by hand. Properly the first thing is to be sure that the key itself is true lengthwise, and that the faces are square in relation to each other. Then the key-grooves in shaft

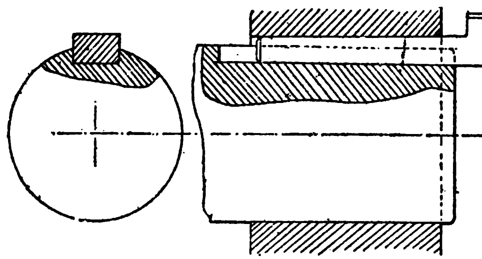


FIG. 25
Gib-headed Key.

and wheel are eased until perfect contact occurs between key and grooves throughout their entire length, red lead being, as usual, employed as a test of contact. If the key bears hard at one end, and is out of contact at the other, or if the groove is winding in relation to the key, then, although the fit may seem tight enough on first driving in, the wheel will work loose in course of time. There should be perfect contact all along at all points. To effect this, the key has to be tried in several times in succession, and the parts in contact eased with the file. It is driven back with the key-drift, Fig. 26, used as in Fig. 27. It is a tool in frequent use, is of steel, and is employed for driving out keys from their seatings. It is

cranked, as shown, to clear the body of the shaft in which the key-way is cut. Sometimes the key is driven from the outside, sometimes from the inside of work—according to convenience of getting out. When driven out from the

FIG. 26
Key-drift.

inside, a piece of lead, or of wood, should be laid between the drift and the shaft—at *a* in Fig. 27—to prevent the latter from becoming bruised.

During the hard driving of keys, seizing is very liable

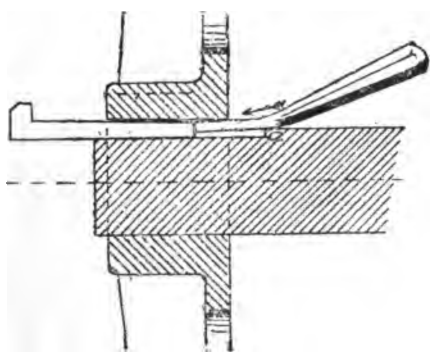


FIG. 27
Use of Key-drift.

to occur unless means are taken to prevent it. Seizing in this case means that the surfaces in contact—namely, of the key and its bed—have been brought into such intimate contact that the metal in each has become partially

amalgamated or clung together. Seizing in some cases is so severe that the surfaces cannot be separated until considerable force has been exercised, sufficient to produce rupture and tearing of the fibres of the surfaces in contact. I have seen this in the case of the bores of wheels drawn too tightly on their axles. It is awkward when it occurs in the fitting of a key, and the risk of this can be easily prevented by rubbing a little chalk on the key, or, better still, a little oil, before driving it in. The presence of oil also tends to prevent seizing by keeping the key cool during driving.

The presence of a few minute filings will often suffice to cause it; hence it is necessary to wipe all filings off keys, and out of keyways, before driving in.

When a key fits properly, it is usual to just finish it by draw-filing on the top, to obliterate the cross-markings. It must be done lightly, just to smooth the surface, without affecting the size or truth of the key in any way.

Removing keys.—To start a key that has been driven home, when the key-drift cannot be used, a wedge is inserted between the head and the wheel boss—at *a* in Fig. 28—and driven in. When driving out with a wedge, it is necessary to hold a hammer under the head of the key; otherwise the wedge will bend the head downwards. This is a device often necessary when two wheels come near each other on the same shaft, or when the key comes close to a bearing from which the shaft cannot be taken out. Frequently, however, it is quite practicable to drive the key out with a drift inserted through wheel arms, in the direction of the arrow, Fig. 28. As in the last case, a hammer must be held under the head to prevent bending of the key.

A similar method is available for getting the key out of a small pinion. The drift in this case passes over the tops of the teeth. As before, a hammer must be held under the head of the key.

When a key is driven in from the back of a wheel

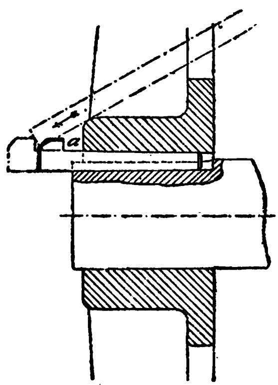


FIG. 28
Removing Key.

instead of from the end of a shaft, then it may be driven out along the key-bed by means of a drift passed through the arms from the front. Another way is to make use of the point of one horn of a spanner, the leverage of which, assisted with hammer-blows, is sufficient to effect the removal of the key.

Keys of this last kind are rather easier to fit than those of the overhanging type. In spite of the holding-up of a hammer underneath the head of the key while driving out, some amount of bending almost invariably takes place. There is no risk of this with the class of keys just named, because they have a bed to slide back in.

There is one other way of getting out keys, adopted in extreme cases when other means of removal have failed, and that is to drive the wheel back from its key; but this is not often resorted to.

Sunk feathers.—With these there is little trouble in fitting, because they are parallel instead of being tapered. The way in which they are fixed to their shafts is seen in Fig. 29.

The feather type of key is used in cases where it would

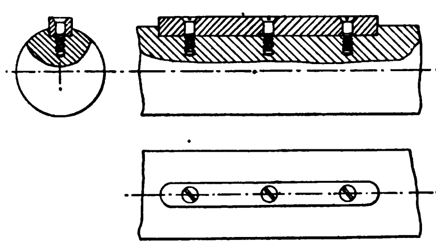


FIG. 29
Sunk Feather Key.

not be practicable to insert the common tapered keys with heads, and also in work which has to slide freely along a shaft, and yet be revolved by the shaft, such as sliding pinions and clutches. In the United States they are termed splines. They are always sunk into key-grooves planed, or slot-drilled, or milled in their shafts. In most cases they are simply driven in tightly; sometimes they are further secured with stove-screws. Small sunk keys are sometimes fastened with countersunk rivets instead of screws, the rivets being stud-screws tapped into the shaft, and having their heads hammered over into holes countersunk in the key. These keys are made of iron or steel, planed on edges and faces. Usually they are tapered on

the top face like common keys, but in what are called *sliding feather keys* they run parallel. When the wheel, or whatever else it may be which has to be secured, has to fit tightly on top of the feather, then no other means are taken to secure it in the shaft. But when the wheel has to slide over the feather, then countersunk screws are used to fasten the feather to the shaft. When the key-way in the shaft has been cut, and the key-way in the wheel has been slotted on the machine, at this stage the work is delivered into the hands of the fitter.

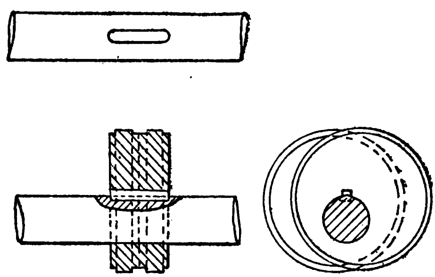


FIG. 30
Keying Eccentrics.

Take first the case of a pair of eccentrics which have to be keyed up, Fig. 30, on a shaft.

The burrs are first taken off the edges of the key-ways, or key-bed, with a file. The feather is, or should have been, left a trifle full by the machinist, and the first thing the fitter has to do is to ease this by filing, until it makes a driving fit with the key-seat in the shaft. It is then driven to make a firm bedding. The top of the feather is next filed off until the eccentrics will go over it a little way by driving. They are then tried on and removed, and

metal removed at the top of the feather at the parts where contact is seen to have occurred, and the eccentrics are again driven over, and the same operation repeated until the eccentrics will drive right up to their proper position.

When driving and trying on, observation must be taken of the fitting at the sides of the key as well as at the top. If, as often happens, the sides of the key-ways have not been slotted perfectly parallel with the shaft, or bore, contact of the key will not occur all the way along. Note must therefore be taken of this, and the key eased by filing where necessary.

The eccentric sheaves should not be struck with the hammer when driving on, but a block of hard wood must be interposed to receive the blows. A metal hammer will bruise the sheaves, and possibly fracture them; a lead or copper hammer would be better, but is not so effective as the use of a block of hard wood, used end grain on. The blows should not be delivered to one side or the other of the key, but plumb over it, and as near to it as convenient —that is, very near to the centre of the pair of sheaves. Blows dealt much away from the centre will make the sheave bear harder against one side of the key than the other.

Tyred wheels often have to be keyed on short axles, in the manner shown in Fig. 31, the wheels running between a pair of bearings. These are keyed up on feathers. The feather is tapered on the top, Fig. 32, as in an ordinary key, and the key-bed in the bore of the wheel is tapered to suit.

Before fitting the key, the wheel is tried on the axle to be sure that the fit is right, a close fit being required without any shake. Burrs, if present, must be removed. The shaft will then be taken out, and the key inserted by

driving into the key-bed. The wheel is stood up on its flanges, as in Fig. 32, so that the axle, with its key inserted as shown, can be tried into the wheel, being knocked in and out readily while the wheel is in the position shown. The details of the work are much the same as those already noted in connection with the fitting of the eccentric sheaves; the top of the feather being filed until a perfect

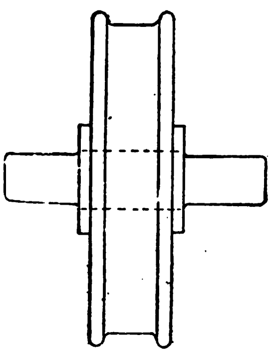


FIG. 31
Wheel Keyed on Axle.

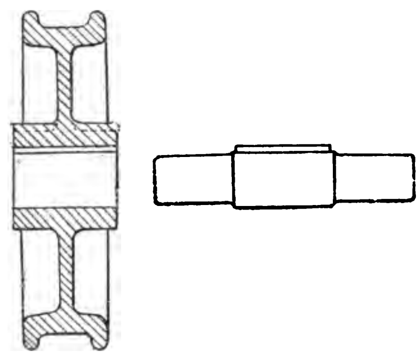


FIG. 32
Wheel and Axle Separated.

fit is obtained, the sides of the feather being looked to, and eased if necessary. It sometimes happens in slotting key-seats in wheels that the wheels are not set horizontally, or else that the slotting-tool springs aside, and the result is that the key-way runs diagonally instead of being perfectly plumb. Then the key has to be eased to follow the seat. A copper or lead hammer, or a block of hard wood, must be used for driving the axle in and out.

When a shaft is keyed into a barrel or drum, as in Fig. 33, one bore is made larger than the other, so as to obviate having to drive the forward key through the first bore in order to reach the further one.

These are examples of heavy, substantial pieces of work, in which there is no risk of damage being inflicted by hard driving. But some slight flimsy castings require tact in handling. Thus, hand-wheels, Fig. 34, are very brittle, and are easily fractured by an injudicious blow. They must, therefore, not be struck on the arms at all when

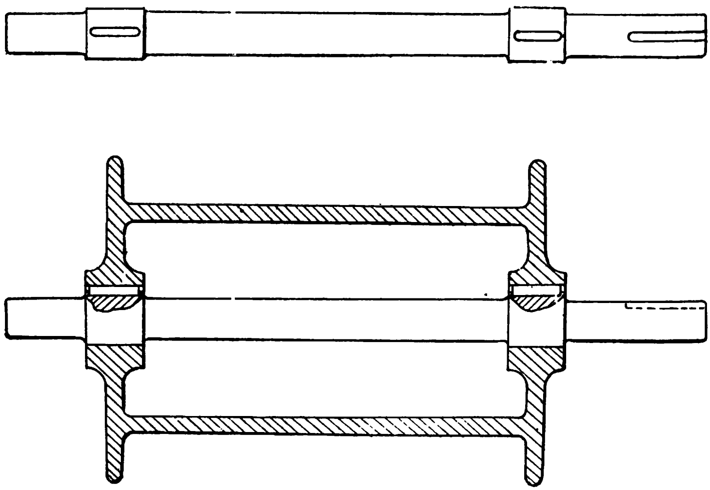


FIG. 33
Keying a Drum.

being driven over the keys, but on the boss only, a block of hard wood being interposed, and the blows must be numerous and light, not few and heavy. The feather keys are tapered on the top, and the key-way in the wheel tapered to correspond. Attention must be given to the proper fitting of the sides, as in the previous examples.

The hand-wheel in Fig. 34 is fitted with a feather key, being situated at some distance away from the end of the

shaft. If the shaft terminates with one face of the hand-wheel boss, of course a key with a head could have been used. Feather keys are necessary when a washer and nut are fitted outside the boss, and when the hand-wheel is inside the bearing.

Belt-pulleys, again, are light castings in which the arms, rim, and boss have to be very exactly proportioned in order to get them to stand. A very little hard driving, or an incautious blow upon the arms will often fracture these while being keyed up.

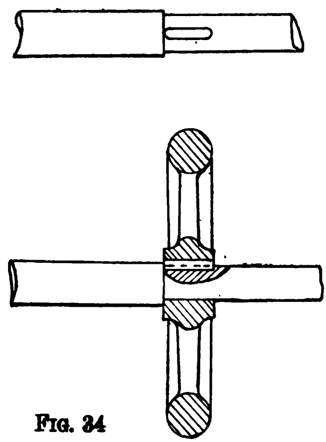


FIG. 34

Keying a Hand-wheel.

The Woodruff key, Fig. 35, fits in a semi-circular recess

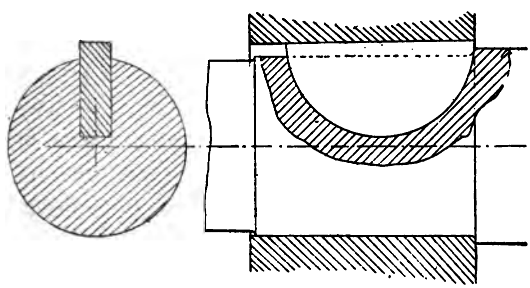


FIG. 35
Woodruff Key.

milled in the shaft, and is proof against shearing and distortion under loads which ordinary keys would fail at. It moreover adapts itself automatically to the taper of the

key-seat in the wheel. Two or more of these keys are used in line for long work.

The class of key shown in Fig. 36 is employed when the wheel or the shaft has to slide while driving, the key being sunk into the boss, and secured with a screw. Two are used for heavy driving.

Split pins and cottars.—A split pin is used when there is risk of the pin becoming slackened and falling out

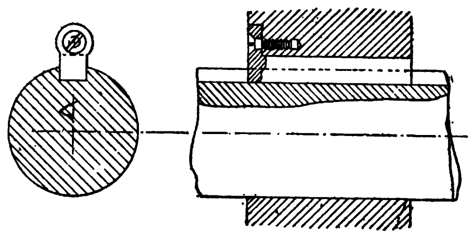


FIG. 36

Key Secured with a Screw.

of its hole by reason of its incessant vibration. The split pin may be a tapered pin, divided for a portion of its length, and opened out after insertion. Or it may consist of half-round wire closed, flat face to flat face, for insertion, and then opened out, Fig. 37. These are very simple and efficient methods of preventing the slackening back of parts which they confine, whether nuts, washers, plates, rods, or collars.

Of similar function are the split cottars, Fig. 38, A. A split cottar is inserted in its cottar-way, and then opened out, and as it cannot slacken back, it confines an adjoining part effectually. There is often no machining on these when they are used for rough work and inserted

in black holes. But for such work they are most efficient. For high-class work other arrangements are made use of.

In various ways cottars properly fitted are utilized in the attachment of parts. They hold parts securely, and possess the additional advantage of allowing a slight adjustment of centres and of diameters from time to time, due to the wear of journals and brasses. They hold entirely by friction, the angle of their sides being considerably less

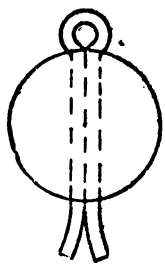


FIG. 37
Split Pin.

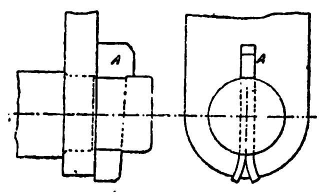


FIG. 38
Split Cottar.

than the angle of repose for iron. In addition, however, they are frequently further secured, in the case of high-speed motors, from the possible slackening back due to vibration, by being furnished with a screwed tail, fastened with a nut and lock-nut, or with a set screw.

When thin straps are secured to connecting-rod ends with cottars, it is necessary to introduce the gib to prevent the opening or spreading outwards of the strap by the driving of the cottar. Double gibs with the cottar between them are often used in the case of large ends, Fig. 39, in which A is the stub end of the rod, B the strap, C, C the gibs, and D the cottar. A set screw prevents risk of slackening back. The taper of cottars varies in practice

within rather wide limits. If there is no screw used for security, the taper is less than when a screw is employed. The diameter, or area, of a cottared bar should be such that its strength through the cottar-way should be equal to that of the adjoining part of the bar which is not cottared. Hence the cottared part is always enlarged. The width of a cottar—that is, taken in the direction in

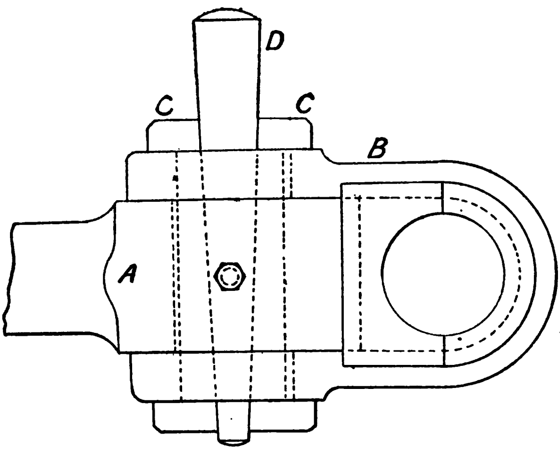


FIG. 39
Gib and Cottar Fitting.

which it is subject to shearing stress—is about equal to the diameter of the enlarged portion of the bar, and its thickness about one-fourth the diameter.

The fitting of cottars is an important and neat bit of work, and is done in some of its stages by hand. The sides of the cottar and cottar-way are always parallel, the taper being wholly at the edges or ends. The sides are slotted out, or slot-drilled, but the tapered parts have to be finished or eased more or less by filing. But in some

shops fitters have to do as their predecessors always had to do—cut everything out by hand, line out, drill, chip, and file laboriously; and such a job is a good piece of practice for students or apprentices who desire to appreciate the difficulties of a piece of good fitting involving the contact of several parts.

Pins.—The fitting of plain round pins into their holes is an important matter. The effects of bad fitting become very noticeable in the case of a series of levers, such as is used for any kind of reversing gear for engines, or for clutch work. If the fitting is tight, then spasmodic tugging at the lever handle becomes necessary. If slack, then there is proportionate back-lash, and the levers do not answer immediately to the pull on the handle, and the resulting movement is not precise and accurate. There are therefore certain points to be borne in mind in making these connections. There is the first fitting, then provision against undue wear, and there is final fitting. The first is done by drill and broach, the second is effected by case-hardening, and the third is done by lapping. We will consider these in turn.

After the forked portions of the levers have been fitted closely, yet freely, either by facing or filing, the holes are either drilled only, or drilled and broached or reamered. If drilled only, the twist-drills should be used, since their guidance is better than that of the flat forms. If the pins do not happen to quite fit their holes, the file should not be employed; but the reamer should be run through. And unless perfect fitting can be insured with the drill in the first place, it is better to drill the holes $\frac{1}{16}$ in. small, and leave this allowance for broaching.

Case-hardening.—But, however good the fit is when first made, comparatively little service will suffice to make the

pins and their holes, and the flat faces which are in contact, wear slack. The practice, therefore, is to harden all the wearing surfaces, leaving other parts soft. The method is called case-hardening, because the soft interior is encased with a surface skin of hardened metal. The usual practice of case-hardening is as follows:—

The work is first fitted up by machining or otherwise, and then taken quite apart—all pins taken out of their holes, nuts unscrewed, &c.—and each single part hardened when removed from contact with its adjacent portions. In addition to pins and their holes, many sliding surfaces in wrought iron—as link motion, and also nuts that have to be frequently removed—are treated thus.

There are two general methods by which the hardening is effected—one called *potash-hardening*, the other *box-hardening*. In the first, a clear hollow fire is made up—usually on the forge—and the work taken and heated, a piece at a time, to a fair red heat. It is then removed with the tongs, and yellow prussiate of potash, powdered, is spread over it with a spoon or spatula of metal. The heat of the iron fuses the potash, so that it runs, and forms a glassy coating upon the iron. This may be done once only, or the process may be repeated two or three times, and the iron plunged while still at a low red heat into the water-bosh. The hardening effected in this rough-and-ready manner will penetrate to the thickness of a sheet of stout paper.

Box-hardening is done in a more substantial manner. A stout cast-iron box of circular, or of rectangular form, and of a size suitable to the nature of the work, is used. The box must be of good thickness, in order to withstand the warping effects of the heat of the furnace. A box 2 ft. in diameter should be 1½ in. or 1¾ in. thick. It is

PLATE 1.—Shop of Kendall and Gent, Ltd., Manchester. [*Facing p.* 48.

provided with a loose cover of cast iron, of about the same thickness. Into this box the hardening mixture and the ironwork are put, in alternate layers. The mixture used generally consists of crushed bones, horses' hoof-parings and old leather belting, in about equal parts. A little salt or potash assists the activity of the ingredients, and is therefore frequently added.

Method of packing.—When laying the work in the box, care is taken not to jumble it in promiscuously, but to give it proper support upon the powdered mixture. If this precaution is not observed, the prolonged heat of the furnace will cause slender parts to become bent and warped much more than if proper support is afforded them.

To pack work, a thickness of about ½ or ¾ in. of spent bone or of charcoal is laid in the bottom of the box, a layer of work is put on that, then a layer of bone or other cementing material, then another layer of work, and so on, until within about 1½ or 2 in. of the top, when a final layer of spent bone or of charcoal will cover over the whole. The cover is luted with fire-clay. The smaller the pieces the thinner the packing need be; for heavy pieces the thickness of packing must be increased. This applies also to the distance between the work and the sides of the packing box.

The smaller the work, the lower and less prolonged will the temperature be. A cherry red maintained for about three hours is suitable for the smaller work, larger pieces requiring any period between that and twenty to thirty hours. In the ordinary class of hardening done in engineers' shops with mixtures of indeterminate strength the latter periods are often allowed. With preparations of bone, periods of from fifteen to twenty hours are ample to harden

to a depth of from $\frac{3}{32}$ to $\frac{1}{8}$ in. To harden heavy work the temperature is allowed to rise higher than for smaller work, or to a bright orange or white heat. At such temperatures the risk of distortion is great, the forgings become soft and ductile, for which reason the packing must be done more carefully for high and prolonged temperatures.

All night is sufficient for much work; for deep hardening a day and a night is allowed. If a test piece be broken, the hardening in the first case will be found to have penetrated from $\frac{1}{64}$ in. to $\frac{1}{32}$ in.; in the second from $\frac{1}{16}$ in. to $\frac{3}{32}$ in., sometimes even to a bare $\frac{1}{8}$ in.

There is no advantage in average engineer's work in hardening to a greater depth than from $\frac{3}{32}$ to $\frac{1}{8}$ in., and for most forgings $\frac{1}{16}$ in. is sufficient. As it is not possible to ensure uniform thickness in even a single piece, it often happens that in some parts the thickness will be greater than desirable, and in others the thickness will be at a minimum. The only remedy is to use metal as homogeneous as possible, and to employ well-selected cementing material.

The chilling of the work must be effected quickly. The forgings will not suffer by being permitted to cool slightly in the box, provided they are not exposed to the air. But directly the box is opened, the forgings must be thrown into the bath. This is more necessary when the objects are to be coloured than when the hardening is the only object sought. Boxes are generally emptied by being turned bodily over, throwing the entire contents into the bath, a better plan than picking the work out with tongs. But the cementing material has to be dried before it can be used again. It is necessary that the water be quite cold to produce the best effects. There should therefore be a volume of water sufficiently large to absorb the heat

quickly, or else a running stream ot water. Sometimes a sieve is suspended in a bath to receive the work, which can be lifted out bodily when cold, and permit of the separation of the cementing material from the forgings. A bath of water is used perhaps nine times out of ten usually medicated with salt or saltpetre to increase the hardening effect. Oil is, however, employed on some small work, for the same reasons that it is used for hardening and tempering many delicate objects. Case-hardening can be repeated as often as necessary. Better results and less brittleness can sometimes be obtained in two or three shorter heats than in one prolonged heat.

One way in which to ascertain the depth of case-hardening while the operation is proceeding is to use a bar as a tell-tale. This will be of the same material as the metal under treatment, and will be thrust through a hole in the cover of the box. It will be withdrawn at the time when the process is thought to have gone on long enough and quenched in water. It can then be broken across to test the depth of hardening, and if necessary the heat can be continued longer and be again tested.

Mild steel requires a longer period for case-hardening than iron, and a proportionately larger quantity, about one-fourth of cementing material.

Case-hardening should not be carried deeper than is actually necessary for the suitable hardening and durability of the surface. Anything exceeding this is detrimental, because the hardened portion is a thickness of porous steel, which is not rendered homogeneous by hammering, or rolling or casting. By as much as this thickness is in excess of actual requirements is the ductility and toughness of the material diminished.

The case-hardened pieces have then to undergo some

re-adjustment and polishing. They are black, and more or less distorted; pins will no longer enter into their holes, and surfaces no longer make proper contact. No file will touch the surface, and the minute adjustments required are, therefore, made either by lapping or grinding, or, in some cases, with emery-cloth or paper.

Case-hardening can be done on a blacksmith's forge. A ready method is to enclose the article in a tube, packing the space between both with crushed bones or leather cuttings, or charcoal, hoof-parings, or prussiate of potash, or a mixture of all; close the ends with clay, and heat it either in a clear fire or between bricks laid around it. After a sufficient time has elapsed the tube is knocked off and the work quenched. Axle ends can be treated in this way.

Sometimes partial case-hardening of a piece of work has to be effected, such as the necks of spindles. Then the portions which should be left soft are encased in a clay jacket, and yellow prussiate of potash finely crushed is used as the hardening agent for the neck or collars. The clay may be confined by an enclosing cylinder. Another way is to leave the part which has to be soft of an enlarged size. Then subject the entire piece to the process of cementation in the usual way, saving the chilling in water, allowing it to cool down in the box. It will then be carbonized, though not hardened. The excess of metal may then be turned off, removing the carbonized section, after which the portions left intact can be hardened by reheating and quenching in water. Pieces which are packed in a box may have parts that have to be left soft encased in clay.

Colouring work is a distinct and special branch of case-hardening. Several precautions are necessary, one of

which is perfect cleanliness of the surfaces to be coloured. The bone used for colouring must be also perfectly free from greasy matter, the heat must not exceed a cherry red, and the work must be dumped into water without giving any time for the air to come into contact with it. Soft water must be used. Colours are not produced if heats are too long continued. When work has to be deeply case-hardened and coloured in addition, the proper course is to harden at a first operation and colour at a second, cleaning the surface of the work in the interval.

Very small articles may be case-hardened without employing any kind of closed vessel, a sheet-iron tray being used instead. A layer of bone dust being spread over the bottom of this, the articles are laid upon it, each one away from contact with the rest, and completely covered and protected with a layer of bone dust. The tray is then heated to a cherry red for from half-an-hour to an hour over a fire, after which the forgings are thrown into water. The temperature must not exceed that indicated by a cherry red.

Hardening mixtures.—When heterogeneous mixtures of leather, bone, etc., are made up in shops there is always some uncertainty respecting the exact results which may follow. For several years now, therefore, both in England and America, preparations of pure bone have been offered for sale. The raw bone in which greasy matter is contained is not so well suited for satisfactory work as those preparations from which the greasy matter has been expelled. This distinction is of less relative importance when the object is merely to harden, than when it is to colour as well as harden. The presence of greasy matters has the result of leaving colours on the surface which are not permanent. Hence raw bone must be charred before

using it for colour work. This charring is done in the ordinary small case-hardening boxes, the dying heat of a furnace after the fire is drawn being sufficient for the purpose. Palfreyman & Co., of Manchester, subject bones to a process by which an excess of carbon is added to them. The bones are ground, then charred in retorts, and charged with a carbon extracted from a pure hydrocarbon, by which also absorption of moisture is prevented.

Bone preparation is sold in different sizes of mesh to suit work of different dimension, the smaller mesh for light articles, the larger for heavier work. The granulated bone supplied by the Rogers & Hubbard Company is in five sizes, Nos. 1 to 5; the first, suitable for heavy work, passes through a mesh of $\frac{1}{4}$ in. square; the last, suitable for finest work, through a mesh $\frac{1}{12}$ in. square to the finest dust, the other sizes being intermediate.

Bone may be used over and over again after thoroughly drying it, about a third part of new being added to two-thirds of the old. The spent bone can also be utilized to form the bottom layer in a box upon which the work is spread, and also the top layer after the packing is completed.

Leather which has been charred is used alone for case-hardening. It is more rapid in its action than bone, and is sooner exhausted. It must be free from all foreign substances, such as bits of metal. It is not suitable alone for deep hardening, its strength being used up in about three hours. Leather must be burnt to a cinder before it is used, then crushed to powder. Bone and leather may be mixed together in a case-hardening box, or they may alternate in layers.

Coarse charcoal powder is used for case-hardening, the work being embedded in it in a similar way to that adopted when bone or leather is used.

CHAPTER V

SCREWS, BOLTS AND NUTS

Screws.—The forms in which screws are used are very numerous. A multiplicity of screw attachments in various forms are employed in the union of fitted parts. Some few have a limited use, but the majority are employed very extensively in general work. It is not always easy to give a reason why a particular form of screw should be selected for a particular job, but in most cases the reason is that there is no alternative method really practicable.

The bolt.—The typical form in which the screw is used

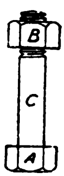


FIG. 40
Common Bolt.

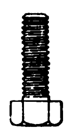


FIG. 41
Set Screw.

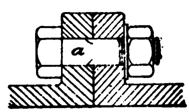


FIG. 42
Bolt uniting Pipe Flanges.

is that of the common bolt, Fig. 40, with Whitworth or other standard thread. This is almost invariably employed when the form of the parts to be united will allow room for the bolt head and nut. Fig. 41 is not called a bolt, but a set screw. It is not nearly so secure a fastening as Fig. 40.

The simplest illustration of the use of Fig. 40 is that of

a couple of pipe flanges, Fig. 42. Common bolts are usually forged circular right down to the head A, in Fig. 40, and fit in round holes. Then the head has to be held with one spanner to prevent it turning round, while the nut B is screwed up with the other spanner. But where a large number of similar flanges have to be united, as in tank plates, it is usual to have bolts with square necks (*a*, Fig. 42) to fit into square cored holes, thus doing away with the use of one spanner. Or, as in high-class work, a

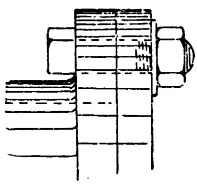


FIG. 43
Bolt with part of Head cut off.

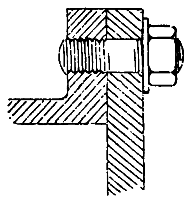


FIG. 44
Stud uniting Flange and Cover.

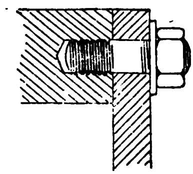


FIG. 45
Stud in a Blank Hole.

small nib under the ball head fitting in the hole, prevents it from turning. See Fig. 48, p. 59.

Round bolts fit into either cored or drilled holes. In all the best work, both large and small, the bolt holes are drilled, and the bolts are turned on the body (C, Fig. 40), so making a close fit with their holes. This is essential, because loosely-fitting bolts permit of vibration of parts, and of movement of these parts in relation to one another, and so cause loosening and undue stress. With tightly-fitting bolts there can be no such vibration.

When holes are cored it is always necessary to make the holes from $\frac{1}{16}$ in. to $\frac{1}{8}$ in. larger in diam. than their bolts. Holes must be cored with much accuracy if only $\frac{1}{16}$ in. is allowed. The usual practice is to allow $\frac{1}{8}$ in. Even then

there is frequently so much difference in the centres of the cored holes, that the bolts will barely fit owing to the partial overlapping of the holes.

In cases where there is no flange available, or else not sufficient room behind the flange for a bolt head, then either a set screw (Fig. 41) or a stud (Figs. 44 and 45) is used. In some instances, and not infrequently, the head is cut off flush with one side of the bolt, as in Fig. 43. But this is a makeshift, not recognized as standard practice. Of the two methods of union by set screws (Fig. 41) or studs (Figs. 44, 45), the latter makes by far the better and more secure fastening. Set screws are never used for heavy work, or for work subject to great stress or vibration. They would be very apt to slacken back, and there is no simple method of affording them security against this, as there is with the nuts of studs. The set screw is not a suitable means of attachment for any except small and light work, and for temporary attachments, as when its function is that of a pinching screw. If a set screw, like Fig. 41, is of only moderate length, tightening it up puts torsional stress and spring upon it that is not conducive to a good hold. Of course, for small work, there is nothing simpler and better. It is

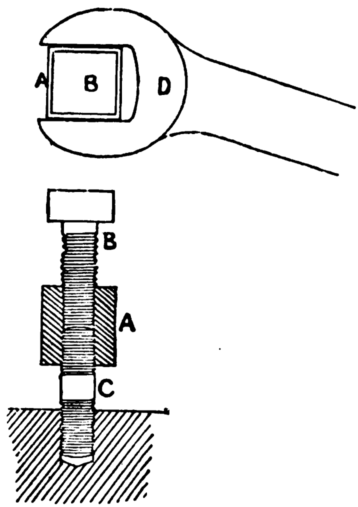


FIG. 46
Stud Block.

very well in its proper place; and with heads of hexagon, square, cheese, or button-shape is extensively used.

The stud.—The stud screw (Figs. 44, 45) is a piece of iron or steel rod, either turned, or left black, as bolts are, according to the class of work for which it is used. It is tapped indifferently, either into a thoroughfare hole (Fig. 44) or into a blank hole (Fig. 45). A special tool termed a *stud block* (Fig. 46) is used for turning it in. The block A is made of steel, square outside, and screwed throughout to the same size as the stud for which it is used. It is fitted with a set screw, B. The stud block is run over the stud C, which has to be screwed in, and the screw B, bearing upon its end, prevents the block A from turning upon the stud. The spanner D, then embracing the square part of the block, is able to turn the stud C into its tapped hole, as tight as is necessary to enable it to resist the leverage of a spanner in screwing off the nut subsequently. When the stud is screwed in to its proper depth, and suitable degree of tightness, the square block A is run back and off.

In the absence of a stud block, a couple of nuts locked together will serve the purpose, but they take longer to put on and take off than the stud block. Studs can be removed also with lock nuts.

Occasionally, on some machine parts, it is desirable that *circular nuts* should be used. Then round holes are generally drilled in the nuts for the insertion of a *tommy*, Fig. 47. The steel nib, *a*, being inserted in one of the holes drilled in the nut, the leverage exerted on the end of A pulls the nut round.

Often, however, the heads of bolts are made of circular form, the nuts remaining hexagonal. This is done when space is restricted, and sometimes for appearance' sake.

Eccentric straps, and connecting-rod brasses of the marine pattern are often secured with bolts having round heads. In cases of this kind, a little nib, Fig. 48, A, is driven or

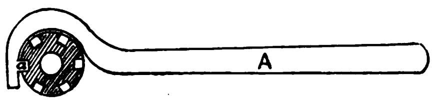


FIG. 47
Tommy.

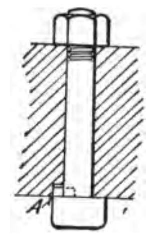


FIG. 48
Bolt with
Circular Head.

tapped into a hole drilled underneath the shoulder of the circular head of the bolt, and this is made to fit in a recess of similar form cut out in the bolt hole. These are the commonest types in which bolts occur, but the following forms are also of very frequent occurrence.

Special forms.—Collar bolts of the two forms shown in Figs. 49 and 50 are used when it is necessary that the movable portion of a mechanism shall be adjustable without taking the body of the bolt out of its fixing. Thus, Fig. 49 shows one of these bolts passing through one end of a plummer block, A. Such blocks are bolted to the angle-irons B of wrought iron crab and crane sides and other structures. The cap C is removable without moving the block A. The shoulder D of the bolt is usually square, fitting into a square recess in A, and the nut E can then be tightened without taking any means to secure the bolt from turning round with it. This is a very useful type of bolt.

When the circumstances are such that neither square nor round collars can be conveniently made use of, and also in cases where a loose removable piece corresponding with C in Fig. 49 has to be tightened close down upon a piece corresponding with A in that figure, then the collar is of the countersunk and circular form, like Fig. 50.

Fig. 51 is a combination form consisting of a stud screw

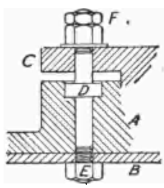


FIG. 49
Collar Bolt.

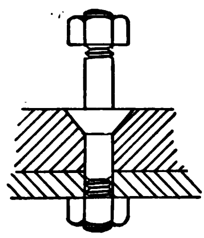


FIG. 50
Collar Bolt for countersunk hole.

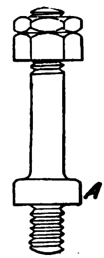


FIG. 51
Gland or Pillar Bolt.

provided with a collar A, and called, from its very extensive use for the glands of stuffing-boxes, a gland bolt. It is also frequently termed a *pillar bolt.* It is simply a stud, like Fig. 44, with a collar A in addition.

Fig. 52 is a *hook bolt,* employed when, for some reason or another, it is undesirable or impossible to have bolt-holes in both of the plates that are to be united. In the figure the lower plate terminates at A, and the upper one, B, alone is drilled. This is much used in boiler-makers' plated work. The *jagged bolt,* Fig. 53, is used for bolting engines and machines down to their foundations, and occasionally for bolting light work against walls—seldom, however, for the latter purpose, *strap bolts,* Fig. 55, being much more secure. The tail A of the jagged bolt is not only tapered, but is hatched or jagged up with a hot sett on

all four corners. It is let into a hole, B, of tapered form in the stone or concrete, C, but of considerably larger size than the tail, and liquid grouting stemmed around it,

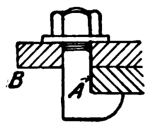


FIG. 52
Hook Bolt.

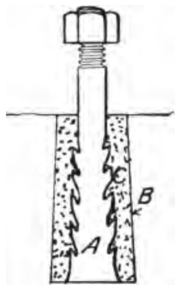


FIG. 53
Jagged Bolt.

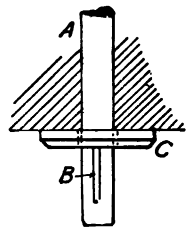


FIG. 54
Cottar Bolt.

which, when hardened, renders the bolt as secure as if held in solid stone.

Fig. 54 is a *cottar bolt*. This is made much use of in

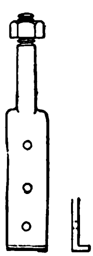


FIG. 55
Strap Bolt.

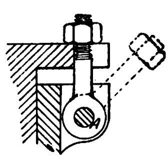


FIG. 56
Eye Bolt.

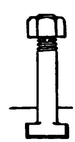


FIG. 57
Tee-headed Bolt.

the foundations of machines that are built upon concrete. The body A of the bolt, in most instances several feet in length, is built in with the concrete. It is square at the lower end, and pierced with a cottar-way, B. It passes

through a square cast-iron washer, C, cored with a square hole. The washer being built in the concrete, and the cottar being driven in B, affords ample resistance to the tightening up of the nut at the other end of the bolt.

The *strap bolt*, Fig. 55, is the best security to structures held against a wall or buttress. These bolts pass alongside, and the tail usually being turned round at right angles for letting into the stone, or for embracing its outer face, and being, moreover, sometimes secured with cross bolts, it follows that either the threads must strip, or the wall give way before the structure or machine can lose its hold.

FIG. 58
Round-headed Bolt.

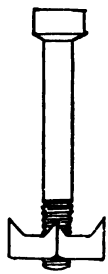


FIG. 59
Fang Bolt.

The *eye bolt*, Fig. 56, is employed when neither a stud nor a bolt with head can be utilized. A stud, A, is tapped into the side of a piece of work, and is embraced by the eye of the bolt. This method is occasionally employed in the stuffing-boxes of large pumps cast without lugs. It is also a useful expedient to employ when a lug, into which a screw or bolt had been secured, breaks off by accident. It has been largely made use of for fastening the cast-iron male and female rings with which large steel pipes are connected. (See Fig. 243, p. 290.) Lugs are cast in pairs upon the rings, and an eye bolt fits within each pair of lugs, pivoting by the eye upon a pin passing through a pair of lugs on one ring, while the nut takes its bearing upon the corresponding pair of lugs upon the other ring.

The *tee-headed bolt*, Fig. 57, is sometimes used on the stuffing-boxes of sluice cocks. It allows of this portion of

the casting being shortened by saving the space which would be required for screwing studs. It is also a movable bolt, employed for securing work to the tables of planing, slotting, and shaping machines.

The *round-headed bolts* with square necks, Fig. 58, are only used on timber work, and seldom by fitters, except for heavy timber work used in constructive engineering. The same remark may be made with reference to the *fang bolt*, Fig. 59.

Lock nuts.—In structures subject to much vibration the nuts are liable to slacken back, and various modes of locking them are resorted to. The commonest device is to screw two nuts instead of one upon the tail of the bolt, as in Fig. 49. Usually one, F, is thinner than the other, and is called the *lock* or *jamb* nut. As the two are not likely to slacken in unison, this is a good security. The thin nut is put sometimes on top, sometimes below the other. Also, it is a very frequent practice to use two nuts of the same thickness, thus diminishing the risk of stripping in nuts subject to great stress, and saving the trouble of turning a nut down thin.

Some of the commonest forms of lock nuts are shown in succeeding figures. Figs. 60 and 61 show the ordinary device of putting an extra nut on the screw, and tightening it up to lock the main nut. Castellated nuts, Fig. 62, are used in conjunction with a split pin or a cottar, which prevents slacking back; the pin is passed through whichever slots happen to come in line with the hole in the screw when tightened up. Another device is to make an extension below the nut with a turned groove, into which the end of a set screw enters and prevents movement. The collar may be sunk into the face of the work, as in Fig. 63, a plan frequently followed

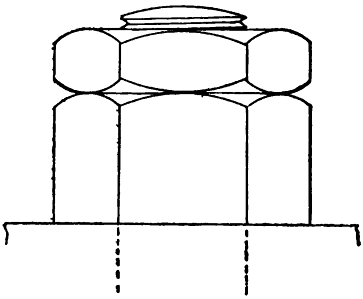


FIG. 60
Lock Nuts.

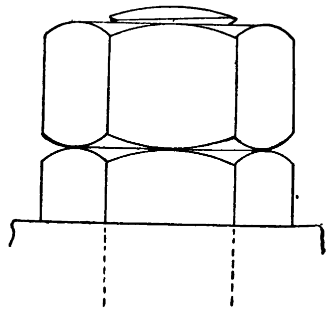
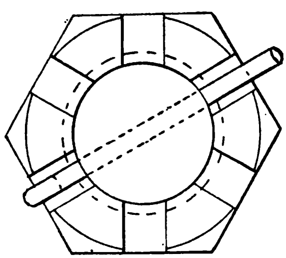


FIG. 61
Lock Nuts.



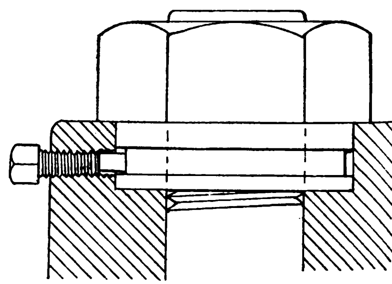


FIG. 63
Nut with sunken Collar and Set Screw.

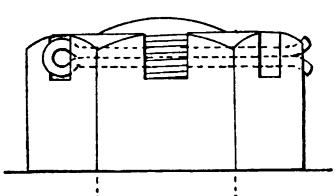


FIG. 62
Castellated Nut.

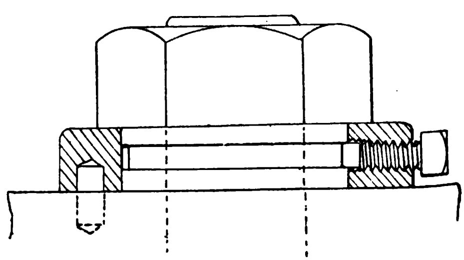


FIG. 64
Nut with raised Collar and Set Screw.

in large connecting and other rods, or a ring may stand up from the work, Fig. 64, and receive the set screw, the collar being fixed with a pin to prevent it turning.

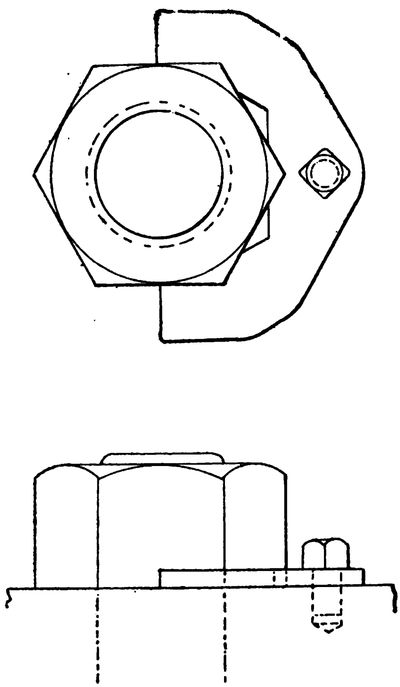


FIG. 65
Nut locked with Plate.

Fig. 65 shows a thin plate made to embrace three sides of the nut, in either of two positions, and secured by a set screw. Large nuts are sometimes partly slotted through, *see* Fig. 66, and fitted with a set screw, which springs the parts together and binds the nut on its

screw. The "Helicoid" nut, Fig. 67, forms a lock in itself, being made from rectangular bar wound in spiral form,

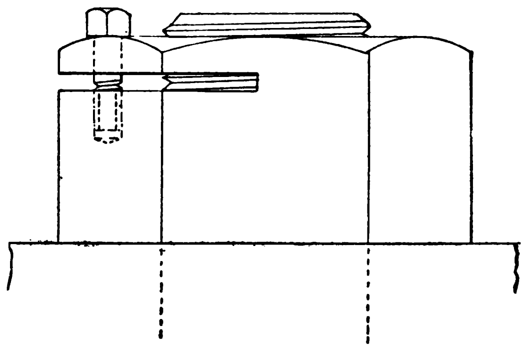


FIG. 66
Nut locked with Set Screw.

cut off and tapped and faced; when it is screwed up the springiness of the coil binds the nut on its thread with a grip which vibration cannot loosen. The Grover spring washer is another good device, Fig. 68, consisting of a ring sprung apart, so that when the nut is screwed down there is a constant end pressure tending to prevent slacking back. The Thackray washer is somewhat similar, with a double coil of thinner metal.

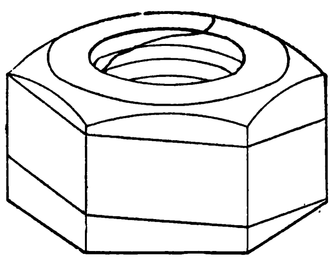


FIG. 67
Helicoid Nut.

A common way by which nuts are prevented from slackening off is by means of *split pins*, Fig. 69. The pin is driven through a hole drilled in the tail of the bolt upon the top of the nut.

This is not a good method, excepting in cases where the position of the nut upon the screw is invariable, as when the bolt unites portions whose faces abut permanently.

These are the principal methods in use. The various

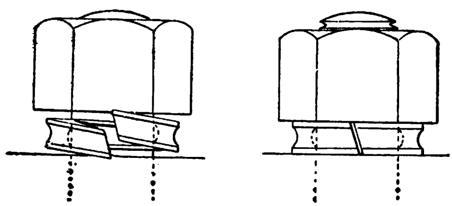


FIG. 68
Grover Spring Washer.

nut-lock and spring-washer arrangements, right- and left-handed threads, and so on, whose name is legion, are used for special and high-class work.

There are two forms of nuts employed not unfrequently that should be mentioned. One is the flange nut, the

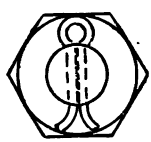


FIG. 69
Nut with Split Pin.

FIG. 70
Flange Nut.

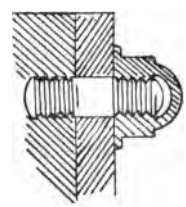


FIG. 71
Box Nut.

other the box nut. The *flange nut*, Fig. 70, is a substitute for the ordinary nut and washer. The flange is, however, usually larger than the standard washer. It is useful for the purpose of covering over a large hole, or as a neat finish.

The *box nut*, Fig. 71, is employed where, owing to exposure to rain, steam, or leakage, the common nut would become rusted upon its screw, and difficult of removal for purposes of examination or repairs. These nuts protect the ends of their threads from rust. They are usually cast in gun metal from wood or metal patterns, and are mostly flanged, as shown.

Tapping holes.—Holes that have to be tapped should always be drilled first. Tapping cored holes soon spoils the cutting edges of the taps. Similarly, bars that have to be screwed should either be turned first to the size, or the scale and skin ought to be removed by grinding. The size of a bar before tapping must be the same as that of the points of the thread, no more and no less. Similarly, the diameter of a hole to be tapped should be exactly the same as that of the root of the thread. If a bar is only a minute amount larger, or a hole smaller than these sizes the labour of cutting the thread is greatly increased. If, on the other hand, the bar is smaller, or the hole larger, the edges do not come up keen and sharp, but show an amount of flat that is unsightly. The hole whose diameter gives the correct allowance for tapping any given thread, is called the *tapping-hole* for that thread, and fitters keep drills by them ground to correct sizes for the roots of all standard threads. Tapping-holes in cast iron are, however, frequently drilled a very trifle larger than those in wrought iron and steel, because the edges of the threads in cast iron will not come up quite so clean and sharp as those in wrought.

Tapping.—Tapping requires to be done gently and cautiously. Clumsy rough working will often have these results: The tap may become broken; the cutting edges

of tap or dies may be broken more or less; the thread may be torn and jagged, or its surface be roughened up. These are evils to be avoided. When screwing, therefore, the pressure should not be excessive. This is a matter for the sense of touch. A little practice will soon tell a man when he is forcing the screwing tackle. There is a difference in the feeling of *cutting* and that of *squeezing* and grinding. If cutting properly, there should be no elasticity in the lever in the backward direction on removing the hand. Neither should the tap or dies get more than moderately warm. During cutting they should be lubricated with oil, and after turning two or three times in the cutting direction, the lever should be moved back a turn or half a turn, to relieve the friction.

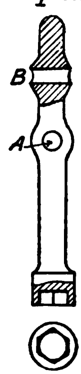


FIG. 72
Box Spanner

Spanners should be cranked at an angle of 15° with the shank. Then they will turn square nuts in 45°, and hexagon nuts in 30°. The length of shank should be eight or nine times the width between the jaws. I need not illustrate these, nor the screw wrenches. Fig. 72 shows a box spanner, used where nuts are in a position so confined that the ordinary spanner cannot be turned round. A podger, or any suitable piece of round bar, is inserted in one or other of the holes A B, as most convenient, and give the necessary leverage for turning the spanner.

Fig. 73 shows a podger employed for two purposes. The tapered end A, of round section, is used for pulling drilled or punched holes into line, so that their bolts or

rivets can be inserted. The flattened end B is used like the end of a crowbar for lifting up and slipping along a

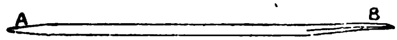


FIG. 73
Podger.

casting or forging into position, or for prising open flanges or plates that are in close contact.

CHAPTER VI

MEASUREMENT

Rules.—The rule used by fitters is generally 1 ft. long, and of steel. Joint rules of any kind are not suitable, especially those which are made of wood. When a 2 ft. rule is used that also is of steel, and unjointed. Two, or four edges are usually divided. For the ordinary purposes of the workman two edges are quite sufficient. There is no advantage either in having such fine divisions as 100ths of an inch; 64ths are quite fine enough, and one inch so divided is sufficient. Three, or six inches may be divided into 32nds, and the whole of one edge into 16ths. It is always best that one entire edge shall be left divided no finer than 8ths of an inch. It saves confusion when taking coarse measurements. There is seldom any advantage in having a rule divided into 10ths, or 20ths, or 50ths. If millimètre divisions have to be adopted, as they have on some jobs, it is better to keep a separate rule for them. Besides the 1 ft. or 2 ft. rule, one rule, 6 in. long, is very useful to carry in the pocket. It is well to have all rules nickel-plated.

Straight-edges and squares.—These are very important tools. As a rule, fitters make these for themselves. It is scarcely necessary to occupy space in a detailed description of the methods employed, because every apprentice of

a year or two's standing has made these articles for himself; and, of course, every one knows that to originate a perfectly true parallel straight-edge, it is necessary to make three such. But for workshop use, a straight-edge is made from a standard already in existence, or from a shop surface plate. So also it is known that to make a square true, the edges must be done by trial on straight-edge or surface plate, and then the blade made true with the stock by turning its stock to right and left alternately against the true edge of a plate, correcting the blade until each edge coincides with a line squared up from that edge upon the surface of the plate.

Small squares are made with stock and blade separately, the blade being fitted tightly within a saw groove cut in the stock, and so riveted in. The stock is purposely made heavy, in order that the square shall stand steadily upright upon the stock when being used as a set-square. But large squares are forged from a solid flat bar of iron or steel bent round by the smith. The edges are afterwards planed or filed true. Small squares are as short as 2 in. or 3 in. in the blade, for convenience of carrying in the waistcoat pocket. For bench use, they range from 6 in. to 8 in. or 10 in. in the blade. Large squares may be from 15 in. or 18 in. to 2 ft. 6 in. or 3 ft. in length. Lines over that length are better raised by geometrical methods. The length of the blade of a square may be about twice that of the stock.

Two kinds of bevels are illustrated in Figs. 74, 75, one having a hooked end to the blade, by means of which very small angles can be measured between the blade and the stock, an impossibility with the ordinary bevel which is hinged at the end of a straight blade. The second instrument is a universal bevel, having long slots both in

blade and stock, so that almost any setting can be obtained to suit all kinds of work.

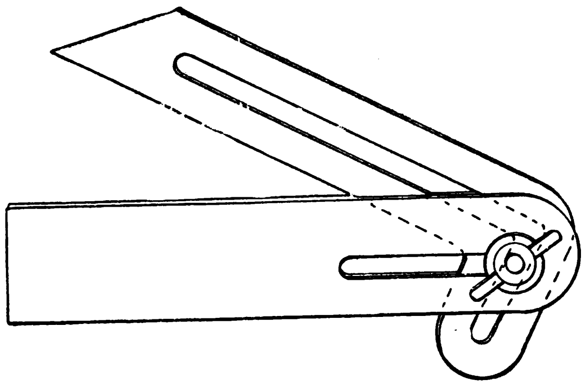


FIG. 74

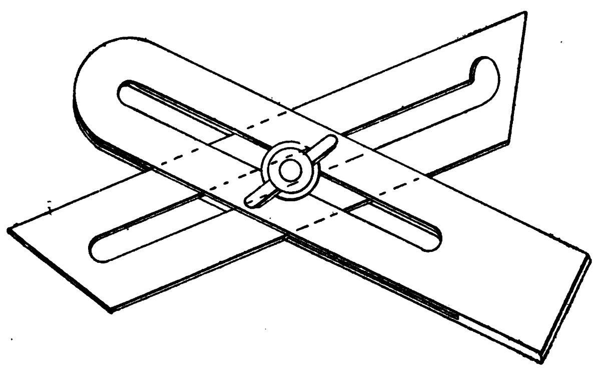


FIG. 75
Bevels.

Scribing instruments.—Lines are invariably marked with pointed instruments. The common scriber is used for lines which are not marked with other pointed instruments.

One end is straight, the other is often curved. This is shown in Fig. 76. It is made in two forms: one, A, with one point only, the other end being frequently bent round; the other, B, with one point straight, and the opposite point turned round for marking the under surfaces of work. In B is shown a twist often given to the body to enable the hand to grip it better.

A tool in constant request is the *scribing block*, or *surface gauge*, and one that is often made by workmen

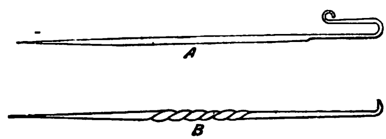


FIG. 76
Scribers.

for their own use. It occurs in perhaps a dozen different modified types.

Its value consists in the facility with which its movable point can be adjusted for height, and made to move in parallel lines with the face of the marking-off table, no matter how irregular the faces upon which the parallel lines have to be scribed. With no other tool would it be possible to scribe parallel lines upon faces in various planes.

It is used to locate centres, and to mark off dimensions and heights from one portion of the work to another, or from an extraneous source of measurement to the work, the straight point being used in such cases. The turned-down point is used to level work on tables, some of the upper faces of which are known to be either approximately or absolutely true, the foot being moved along on the top

surface, and the work adjusted on the table until the top face is in contact with the scriber at all localities, the base or stand sliding always along the bed or table. Accuracy primarily depends upon the truth of the bed or table upon which the scriber is slid. Having a true basis of operation there is no limit to the utility of the scriber. It does not matter how irregular are the faces upon which lines are required. Any number of lines, true and parallel with the base and with each other, can be scribed thereon. However awkwardly centres may be situated, those centres can be marked with absolute accuracy from the base. It is essential that the scriber be steady, for which purpose the bottom is made heavy and substantial. The bottom is faced truly, and should be concave or recessed, so that contact shall occur round the edges, as being conducive to greater steadiness. The design of the upper portion is of little moment, so that there is good range of adjustment of the gauge itself, up and down and lengthwise, and ready and ample means of clamping.

In Fig. 77, both in A and B, the base C consists of a disc of wrought iron, supporting the rod D. In the first figure, A, the spherical head E slides freely, yet closely, upon the pillar D. The head is drilled at right angles to take the circular pin F, which is drilled in turn at right angles with its length to slide loosely upon the pillar. The tail of the pin is screwed to take the wing nut G. Between the wing nut and the hemispherical body, the actual scriber H is slid over the screw. The hemispherical body E is flattened at the spot where the scriber has its bearing. The shoulder of F stands slightly within this flat face. When, therefore, the nut G is tightened against the scriber, the pin F and the hemispherical body E are pulled towards each other, so

tightening around the pillar D, and upon the scriber H, and all is fast.

The scriber shown at B is tightened in a different manner. Upon the pillar D slides a split block, J

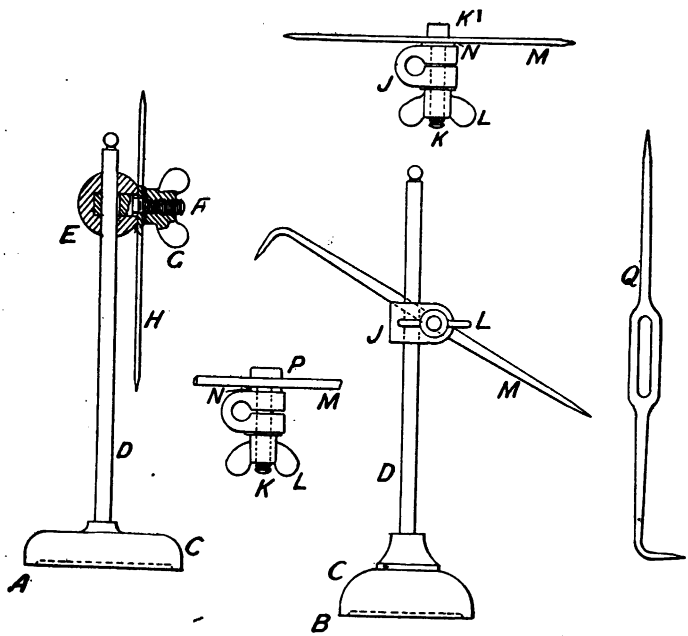


FIG. 77
Surface Gauges.

divided on one side as far as the pillar. Through a hole drilled in this portion, the screwed pin K is passed, and pulled up against the block J, with the wing nut L. The pin K is furnished with a head, K^1. When the nut is screwed up tightly, it pulls the head K^1 against the scriber M, and not only sets the block J in position on

the pillar, but also pulls the scriber M fast against the washer N.

In surface gauges fitted with a split block like J, an alternative plan is to drill a hole through K^1, and, making M of round steel wire, let it pass through the drilled hole. By filing shallow grooves in the washer N, the scriber can be clamped fast against these grooves. This is shown

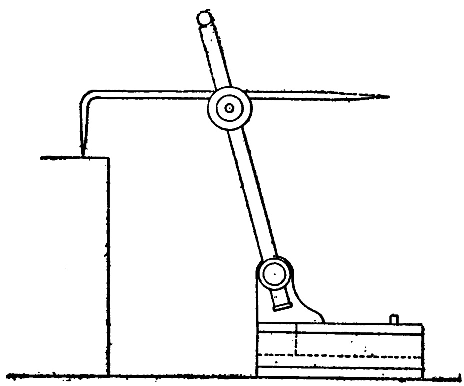


Fig. 78
Surface Gauge.

at P. These indispensable tools are modified in many ways in the shops.

Properly, the scriber should have means of end-long adjustment, as well as adjustment for height. The usual form given to it is that shown at Q, the long slot permitting of movement endwise. At P the same object is secured by the movement of the round rod M, through the hole drilled in the head of the pinching screw.

The instrument in Fig. 78 has a base with vee-grooves for use on shafts, etc., and a couple of pins are fixed on the top near the back, to bear against edges, and run the

scriber along parallel to them, like a marking gauge. The stem is clamped in any position by a sleeve and bolt, in a lug standing up from the block, and the scriber is held frictionally between faces, so that it can be altered finely for height by turning a knurled disc.

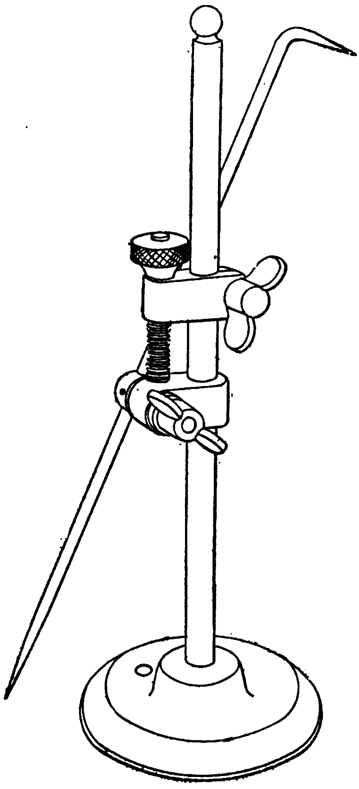


FIG. 79
Billings Surface Gauge.

The Billings surface gauge, Fig. 79, has an upper push-block which is clamped to the rod, and through which a screw passes to raise or lower the lower block. The latter carries the bolt through which the scriber passes, and is secured by tightening the wing nut.

The Starrett instrument, Fig. 80, has its rod elevated by a screw and knurled nut in the base, and clamped by a split bearing there. A notch is cut in the base, to let the scriber pass down, for measuring depths. The illustration also shows how an extension top is used, a longer piece of rod being screwed into the top of the main one, so enabling the block to be raised higher for special purposes.

A surface gauge should not be made in a flimsy fashion, for it will then be unsteady, and mark untrue lines. The base should be stout and massive, and the stem also stout. The lightest portion should be the sliding block and screw.

Trammels.—Two pairs of trammels are required, a small

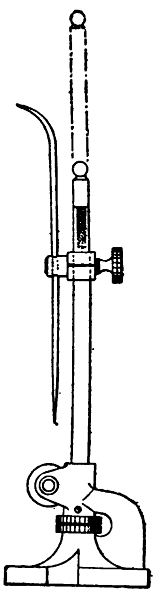


FIG. 80
Starrett Surface Gauge.

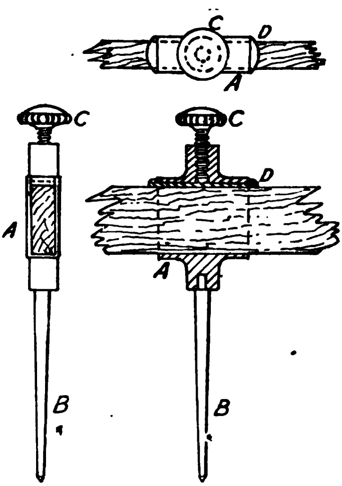


FIG. 81
Trammels.

light pair, and a larger pair. For the small ones, the beam is sometimes of metal, for the larger ones it is of wood. A good type of trammel head is shown in Fig. 81. The proportions to which the figure is drawn are suitable for large or small heads. The length should not be relatively much less than that shown, or the head will be

unsteady upon the rod. The cross section of a small rod may be $\frac{3}{4}$ in. by $\frac{5}{16}$ in., of a large one $2\frac{1}{4}$ in. by $\frac{5}{8}$ in., and others will come between these sizes. The figure is almost self-explanatory of the method of construction. Trammel heads usually are made on the general pattern there shown. A is a casting of gun metal or brass, filed to slide smoothly, and with as little slop as possible, on the staff; B is the pointed leg, fitted either with a screw or by tight driving into the hole drilled in its boss; C is a set screw of brass or steel tapped into its boss, and pressing upon the thin washer D, which is shouldered in plan to prevent it from slipping out endwise. The washer then bears fast upon the rod, and the head is fixed in position.

Compasses and Dividers.—Any ordinary wing compasses and spring dividers are used by fitters; but they are ground to a more obtuse angle than when employed for wood. The points of all fitters' marking instruments must be ground to a larger angle than those for marking on wood, otherwise they will not preserve their edges; and they should be sharpened on an oilstone as often as they begin to get dulled.

Figs. 82, 83, show two common forms of dividers. The first pair have a quadrant over which one leg passes, and is secured with a set screw. The end of the quadrant is screwed, and has a nut by which fine adjustments are made, a flat spring maintaining the tension between the quadrant and the leg. The second pair (Fig. 83) have a spring head, with a knurled holder for twirling the instrument when doing small circles, and the legs are closed by turning the nut on the pivoted screw. The nut is of the quick-action type, that is, the thread is cut in little spring jaws, which stay in contact with the screw so long as the

leg presses on the nose of the nut; when the user pinches the two legs together, the springy jaws open, and allow the nut to be slid instantly to and fro, instead of having to screw in all the way.

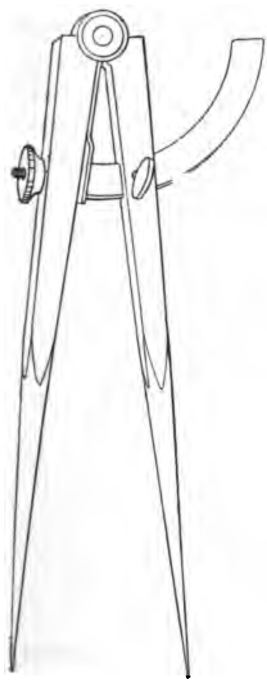


FIG. 82

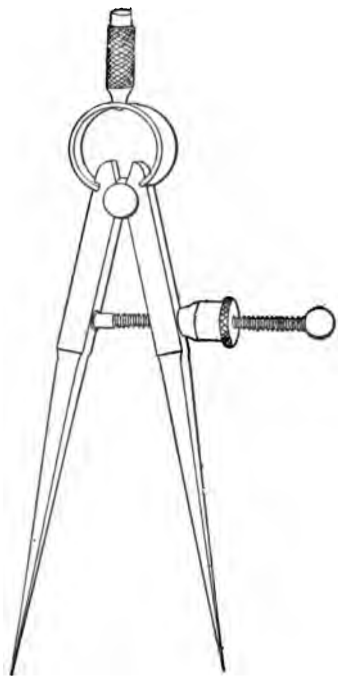


FIG. 83

Dividers.

Calipers.—The various forms of calipers are shown in Fig. 84. There are the outside calipers A, the inside B, the compass caliper C (used for scribing work), and the combination D, where external and internal legs give the same dimensions.

Caliper joints must fit closely, pins must fit their holes exactly, without slop, and to prevent spring, the metal near the pivot end must be much wider and stiffer than at the points, thence tapering well down to the latter; and also the points should be thin, but spread very slightly.

The too tight or too slack fitting of the rivet are equally evils. The first is more favourable to exact setting to dimensions than the second; but the legs are adjusted the less readily. The second evil is greater, because the calipers are so loose that a slight movement is liable to

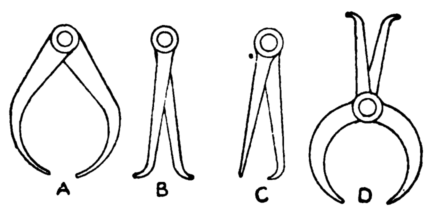


FIG. 84
Calipers.

alter the dimension taken. The fitting should be so nice that adjustment can be made without much trouble and without jerk; yet moving about or laying down the calipers should not cause the legs to alter.

When taking measurements with calipers, they must be held at exact right angles with the axis of the work, to give a correct dimension. To be sure of this, try the measurement two or three times, moving the calipers slightly on their own longitudinal axis, when, if they have been held diagonally, they will be found to be slack if tried square across.

To prevent this tendency to get across, some calipers are made with broad points. But this is not a good plan,

because the parallel truth of the points has to be maintained, and measurement cannot be taken so exactly therefrom as when the points are very narrow. When taking measurements with internal calipers, the same care is necessary as with external. To be sure of getting an exact measurement the calipers must be moved about slightly, otherwise they may get crosswise and give a false dimension.

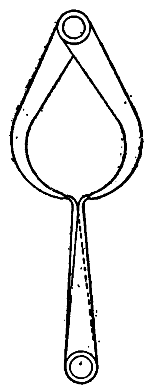


FIG. 85
Checking equal Dimensions with Calipers.

To read dimensions off calipers it is usual to lay one leg against the end of the rule and see what division the other leg comes over. This is rather rough and inexact in the case of a rule which is worn at the end. For accurate results the caliper is tried on a standard gauge. If two calipered dimensions have to correspond, as that of a spindle and its hole, the calipers can be tried on internal and external gauges if such are available. If not, the internal caliper is tried between the external one (Fig. 85).

The practice of knocking calipers to adjust them is avoided in some designs by using a screw, as in Fig. 86, made like dividers, with a spring, and quick-acting nut of the kind mentioned on p. 81. This particular illustration shows wide-tipped calipers for thread measuring. A fine adjustment is secured in Fig. 87 by providing a short extra leg, and moving it by a fine-pitched screw, bearing against a little lug on the main leg. A flat spring in the extra leg bears against a pin in the main leg also, and maintains a tension. The calipers are set nearly to the size, and then finally adjusted by the screw. The key-way

or key-hole caliper, Fig. 88, has a long straight leg, and it is used for measuring distances, such as from inside a boss or key-way to the outside.

In the beam calipers or caliper squares, Fig. 89, one sliding jaw A is moved and finely adjusted by a push-block B clamped to the beam and moving the jaw A by

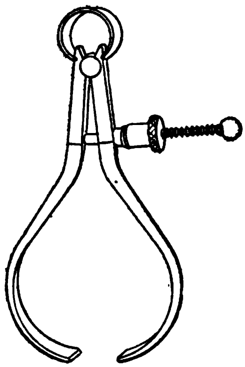


FIG. 86
Calipers with Screw adjustment.

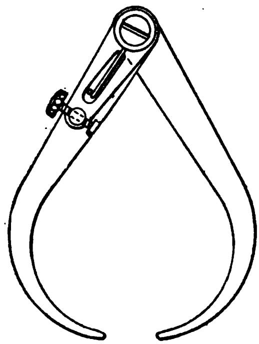


FIG. 87
A fine adjustment for Calipers.

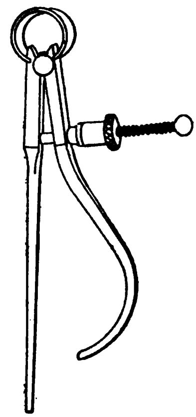


FIG. 88
Key-way Caliper.

a screw, on which the knurled nut *a* is placed. When adjusted, A is secured by its own set screw. A small bevelled block on A has a line marked on it, by which the divisions on the beam are read off.

Micrometer calipers.—In the Brown & Sharpe micrometer caliper, shown partly in section, Fig. 90, at A, the spindle is finely threaded to pass through two nuts in the barrel, one being adjustable by a differential thread, and locked with a nut, so that all slackness can be taken up.

The extension at the end of the thimble is the ratchet stop, a useful fitting by which uniform pressure is always

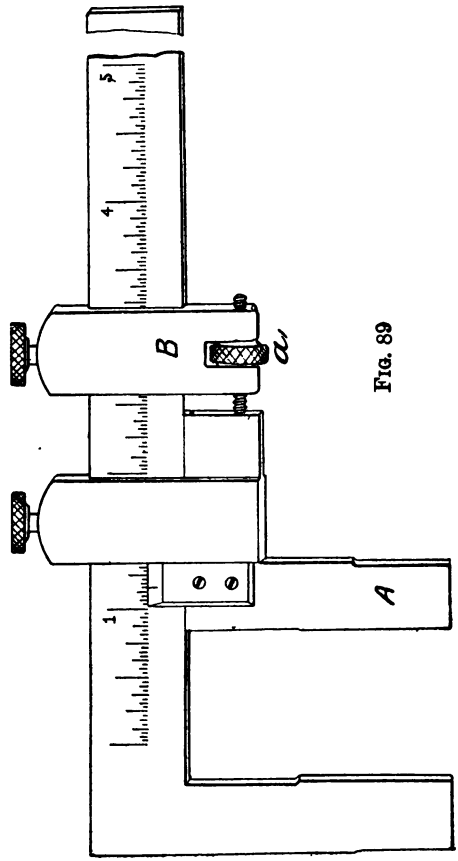


FIG. 89

exercised upon the work. As seen in the enlarged section B, there is a knurled sleeve having ratchet teeth cut on its inner end, into which the spring pawl in the part B

catches. This pawl slips back directly the work is touched by the spindle end, and the screw cannot be turned further. Any number of testers, therefore, would all obtain similar

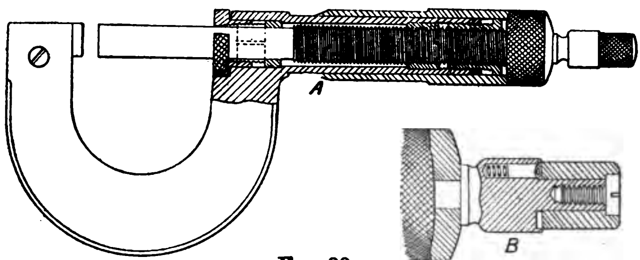


FIG. 90
Micrometer Caliper.

results and identical readings with this instrument. The spindle is locked by a split collar, closed in by turning a knurled nut.

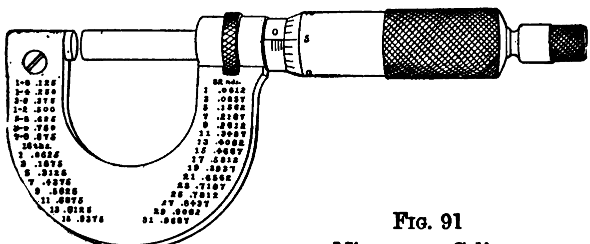


FIG. 91
Micrometer Caliper.

Fig. 91 gives the external appearance of the tool, with its decimal equivalents stamped on the frame. The spindle-locking device is of a rather different type to that shown in the previous figure, comprising a knurled ring

which closes in a split sleeve during a partial rotation, and thus clamps the spindle firmly.

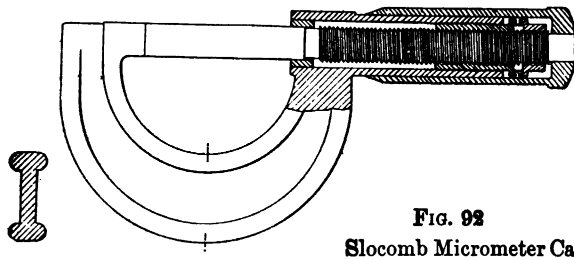


FIG. 92
Slocomb Micrometer Caliper.

The Slocomb micrometer caliper, Fig. 92, has a stamped frame of girder section, and the spindle screw works in a double nut, one portion of which is turned to effect

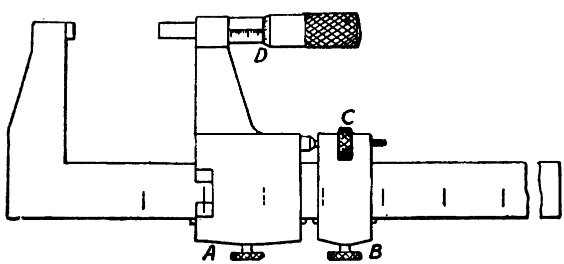


FIG. 93
Combination Caliper.

adjustment for wear, being then locked by teeth on its face engaging with other teeth on the other nut.

Fig. 93 illustrates a combined beam and micrometer caliper, the micrometer barrel D being mounted on the head A, which is adjusted to inch divisions on the beam,

by a push block B and screw C. The intermediate measurements between the inches are then read with the micrometer, the range of which does not exceed 1 in., or in some cases ½ in.

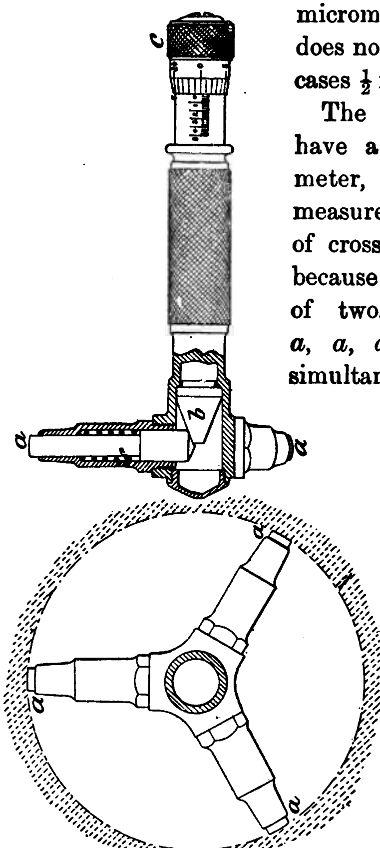


FIG. 94
Internal Micrometer Caliper.

The Newall Engineering Co. have a special internal micrometer, Fig. 94, which will measure accurately without risk of cross-working of the points, because three are used instead of two. The three, marked *a*, *a*, *a*, are moved outwards simultaneously by a coned end *b* of the spindle, which is operated by the micrometer screw and knob *c* in the usual manner. Fine springs around the shanks of *a*, *a*, *a*, press them against the end *b* constantly. These instruments are made up to 24 in. capacity in diameter.

Modern shop measurements. — At the basis of the present-day methods of engineers' work, especially of what is termed *interchangeable* work, lie the problems relating to measurement. This is by no means a simple

matter. On the contrary, its solution has engaged the prolonged attention and labours of some of the best mathematicians and mechanicians during a century past. The workman who uses a Brown and Sharpe micrometer, or a Whitworth or a Pratt and Whitney gauge, seldom knows or considers what great difficulties have had to be faced before the production of these became possible. The mere precision of these and kindred measuring instruments does not ensure accurate work. Many men—good mechanics—can make as good fits without gauges as with them, using common calipers only with skill. Such men will work to a ten-thousandth part of an inch without knowing it, and will probably declare the working to a one-thousandth part to be impossible in ordinary practice. They are right, and they are wrong in this, and the remark will serve to illustrate the essential difference between the older and later methods.

In the first case supposed, the measurement of accuracy—say, within ·0001 of an inch—is an accommodation measurement; that is, a matter of fitting one piece to another. In the second case, working within ·001 of an inch is understood as representing a precise and definite measurement, as tested by some standard of reference There is a very great deal of difference between these two. The first produces as excellent results in regard to workmanship as the second does; but it does not yield the economies of an interchangeable system. The first depends upon the individual workman's ideas of dimensions, his readings of measurements, his rule, his method of handling his calipers, and so on—work in which no two workmen would, independently of each other, turn out two pieces of mechanism precisely alike by these methods, notwithstanding that such pieces would often be

equally good in respect of handicraft, and suitable for the purpose designed. The second method insures the absolute identity of dimensions of any number of similar pieces, not only in the same shop, but also in different shops all over the country, and in other countries as well, so that perfect fits can be insured, if a pin were turned in a Manchester shop and a hole bored in a Philadelphia shop. There is no such thing as latitude in fitting allowed in such a system. An inch means an inch, and nothing more or less. There is no such thing as a full inch, or a bare inch. If a limit is set to variation that limit is stated. It may be a 1-1,000 in. or 1-50,000 in., but these are definite dimensions, and the work done on such a system differs radically from that done on a system of trial and error and of mutual adjustments.

Fixed gauges, Plug and ring gauges.—The commonest gauges are those of the ring and plug type, originated by Whitworth, and now made by many firms. There are wide variations in the degree of precision with which they are made, ranging from 1-5,000 in. to 1-50,000 in. The coarser tools are quite accurate enough for nine-tenths of engineers' ordinary work. The price increases with increase in limits of accuracy. The ordinary cylindrical gauges are of the form seen in Figs. 95, 96, both being preferably knurled for secure handling. In Fig. 95 plain plug and ring types are seen, and in Fig. 96 a limit gauge marked plus and minus at the opposite ends.

These plug and ring gauges are the most commonly used in English shops, because they are convenient, requiring little skill to handle, and because they fit around the entire circumference. They are served badly by careless men, being often forced into and pulled out of holes while work is revolving, or slid over rough-turned

bars while running in the lathe; often, too, without the protection afforded by using a film of oil. Some amount of rough usage cannot well be avoided where gauges are kept for every one's service. It is necessary then to check them from time to time: otherwise misfits will begin to occur between parts turned and bored to the standard gauges, the workmen throwing the responsibility on the gauges, which, in consequence of having become worn, no longer afford accurate means of testing. Such gauges, therefore, require constant watching unless they are to

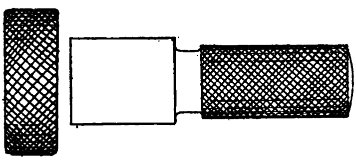


FIG. 95
Plug and Ring Gauges.

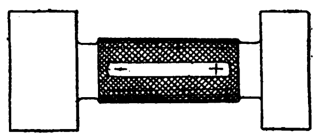


FIG. 96
A Plug Limit Gauge.

become misleading. Their convenience, however, is such that they hold the first place in workshop practice.

Snap gauges.—The *fixed calipers*, or *snap gauges*, occupy the next place. These are not new in type, for specimens of them date back half a century in some of the English shops. The difference between the old and the new is, however, that noted just now—that the older were accommodation gauges, while the new are made to precise dimensions. The snap gauges are flat and thin, so that they measure only in one diametrical plane—a very delicate mode of measurement, precisely like that adopted in testing the bores of large engine cylinders with rod gauges. Care has to be taken not to get them across or out of square; but delicacy of touch soon detects that. The gauges are made with internal and external ends in one forging in the

smaller sizes, but separately in the larger ones. Greater precision is attainable with these than with the ring and

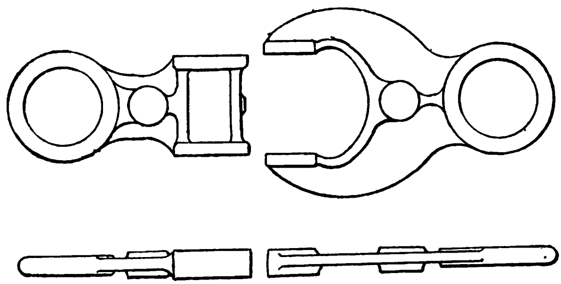


FIG. 97
Caliper Gauges.

plug types, and they are, consequently, more in favour now than formerly. There is a possibility of spring in the larger external snap gauges; but it is so slight that a very little care is sufficient to prevent any false measurements on that account.

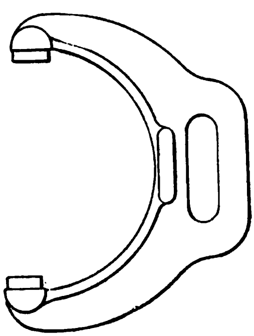


FIG. 98
External Caliper Gauge.

Internal and external caliper gauges, made from drop-forgings, are shown in Fig. 97. The handles are of ring pattern. Fig. 98 is an example of a larger class, with the hardened anvils pinned to the faces of the jaws. Double-ended caliper gauges, Fig. 99, combine both internal and external jaws.

All these gauges are instruments incapable of variation excepting that due to wear, and therein, coupled with the fact of their precise dimensions, lies their value in the workshop. There are,

however, two matters which have to be considered in connection with them. One is the making provision for all the different classes of fits required in interchangeable work, while maintaining precise dimensions; the other is the means for their correction, or, more precisely, for indicating the amount of their departure from exact dimensions.

Limit gauges.—In reference to the first, the gauges are

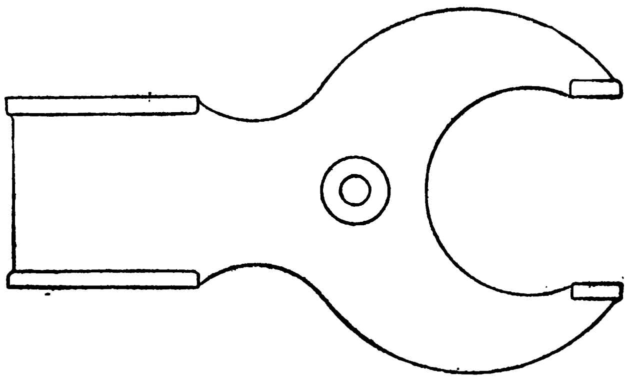


FIG. 99
Double-ended Caliper Gauge.

made within certain limits, larger and smaller than exact standard dimensions. In England we often call them *difference* gauges. It is necessary to set a limit or a difference in interchangeable work, for two reasons. One is to permit of the exact degree of fitting required for any given class of work, without involving the necessity for hand adjustments; the other is to allow for inaccuracies due to the wear of the edges of cutting-tools, and to the slight variations in results which for many reasons are inseparable from work done on machines. The first

condition is distinct from the second; but the sum of the two constitutes the *limit* or *limit of tolerance* within which gauged dimensions are permitted to range. Those limits may be very fine, or comparatively coarse, as the different classes of work vary in their requirements. Limit gauges may be round or flat, internal or external. The words

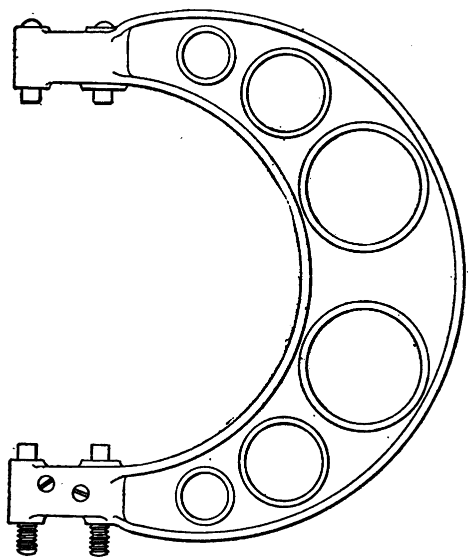


FIG. 100
Horseshoe Limit Gauge.

stamped *go on* or *not go on*, or + and −, see Fig. 96, are for the convenience of the workman, while the number stamped indicates the number of hundredths or thousandths of an inch difference in the limits allowed. By the use of such gauges it is not necessary to make any alterations in grinding or in setting of tools until the limit is passed,

provided the gauges are not worn so much as to require correction themselves.

Large limit gauges are of horseshoe form, with the two pairs of anvils set at the opposite horns, Fig. 100. One pair are adjustable with screw threads, and are clamped with transverse screws.

Corrective gauges.—There are several methods of correction of gauges employed. The commonest is the stepped gauge, and its fellow the simple disc. These are hardened and ground within a high degree of accuracy, not for shop use, but for reference simply. The mode of measurement being that of contact, their employment must be absolutely restricted to the latter function, in order that they shall maintain their dimensions unaltered for an indefinite period.

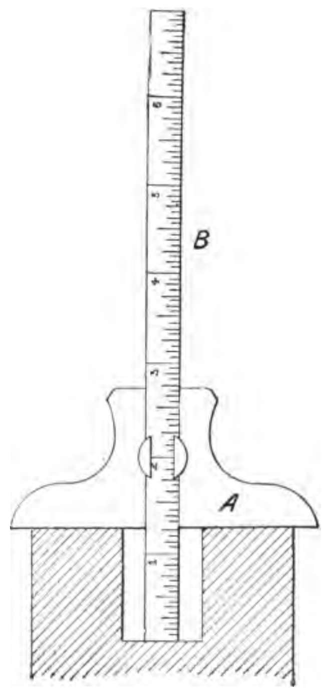


FIG. 101
Depth Gauge.

Another class of reference gauge is the end-measure test piece. These pieces are made in various lengths from $\frac{1}{4}$ in. to 4 in., hardened and ground within 1-50,000 in.

It is necessary to preserve these reference standards as carefully as possible, and they are not therefore kept for

everybody's use. They are in charge of one responsible man, on whom devolves the testing of the shop gauges, and it is necessary to keep them at a normal temperature.

Depth gauges.—Fig. 101 is a depth gauge which has a

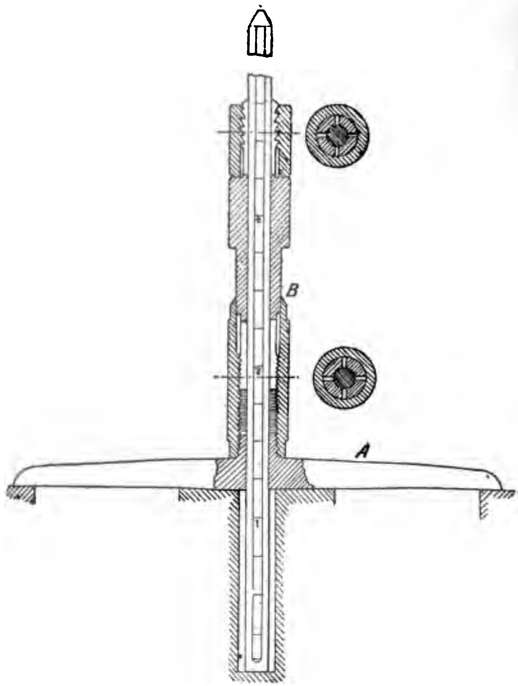


FIG. 102
Depth Gauge.

narrow rule gripped by a hooked bolt, tightened by a wing nut on the back. The depth in inches and parts may thus be read off.

The micrometer depth gauge, shown in Fig. 102, is useful for very accurate work. The foot A has a sleeve B

PLATE 2.—Shop of Greenwood and Batley, Ltd., Leeds. [Facing p. 96.

screwed to it, inside which the micrometer barrel fits. A

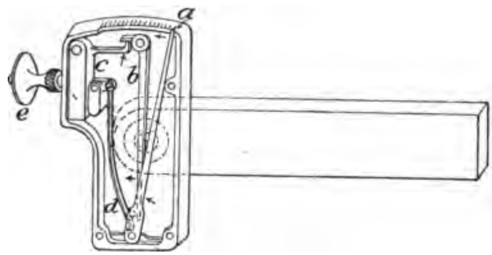


FIG. 103
Bath Indicator.

graduated rod passes right through the centre, and is clamped at the top by a split nose and a knurled nut.

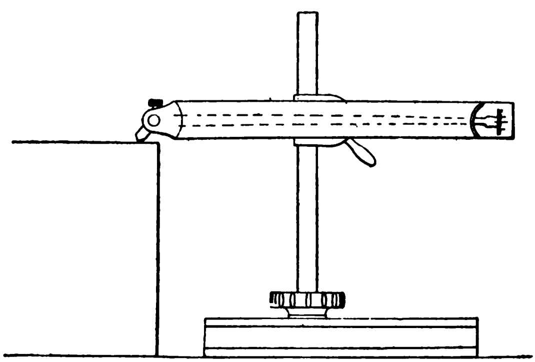


FIG. 104
B. and S. Indicator.

The instrument can be used as an end contact gauge by removing A and screwing on a short round end.

Indicators.—Two kinds of test indicators are seen in Figs. 103 and 104. The first is the Bath, in which a

pointer *a* is caused to move over a graduated edge on the case, by the action of two levers *b* and *c*, backlash being absorbed by a spring *d*; *c* is moved by a feeler *e*, which is touched by the work. The magnification produced by the system of levers is such that a movement of 1,000th in. on *e* shows as $\frac{1}{6}$ in. on the pointer end. By screwing *e* into another hole, lower in *c*, the magnification may be doubled, so that 1,000th in. results in $\frac{1}{12}$ in. of motion of the pointer. Various forms of feelers can be used, according to the class of work being tested. The levers in the case are of course protected by a cover when in use. The Brown & Sharpe instrument, Fig. 104, has a long pivoted pointer hinged so that a considerable degree of magnification is secured, the long end moving over a radial graduated face at the end. The pointer may be set to zero by means of the small knurled screw. The stem of the indicator, to which the body is attached by a split clamping block, is held in a girder-shaped foot, along which it can be adjusted.

Two useful tables are appended—

TABLE OF EQUIVALENTS OF MILLIMETERS IN DECIMALS OF INCHES

$\frac{1}{10}$ mm.	= ·00394″	8 mm.	= ·31496″	18 mm.	= ·70866″
$\frac{1}{5}$,,	= ·00787″	9 ,,	= ·35433″	19 ,,	= ·74803″
$\frac{1}{2}$,,	= ·01969″	10 ,,	= ·39370″	20 ,,	= ·78740″
1 ,,	= ·03937″	11 ,,	= ·43307″	21 ,,	= ·82677″
2 ,,	= ·07874″	12 ,,	= ·47244″	22 ,,	= ·86614″
3 ,,	= ·11811″	13 ,,	= ·51181″	23 ,,	= ·90551″
4 ,,	= ·15748″	14 ,,	= ·55118″	24 ,,	= ·94488″
5 ,,	= ·19685″	15 ,,	= ·59055″	25 ,,	= ·98425″
6 ,,	= ·23622″	16 ,,	= ·62992″	26 ,,	= 1·02362″
7 ,,	= ·27559″	17 ,,	= ·66929″		

TABLE OF DECIMAL EQUIVALENTS OF AN INCH

$\frac{1}{64}$	·0156	$\frac{3}{16}$	·1875	$\frac{23}{64}$	·3593	$\frac{17}{32}$	·53125	$\frac{45}{64}$	·7031	$\frac{7}{8}$	·875
$\frac{1}{32}$	·03125	$\frac{13}{64}$	·2031	$\frac{3}{8}$	·375	$\frac{35}{64}$	·5468	$\frac{23}{32}$	·71875	$\frac{57}{64}$	·8906
$\frac{3}{64}$	·0468	$\frac{7}{32}$	·21875	$\frac{25}{64}$	·3906	$\frac{9}{16}$	·5625	$\frac{47}{64}$	·7343	$\frac{29}{32}$	·90625
$\frac{1}{16}$	·0625	$\frac{15}{64}$	·2343	$\frac{13}{32}$	·40625	$\frac{37}{64}$	·5781	$\frac{3}{4}$	·75	$\frac{59}{64}$	·9218
$\frac{5}{64}$	·0781	$\frac{1}{4}$	·25	$\frac{27}{64}$	·4218	$\frac{19}{32}$	·59375	$\frac{49}{64}$	·7656	$\frac{15}{16}$	·9375
$\frac{3}{32}$	·09375	$\frac{17}{64}$	·2656	$\frac{7}{16}$	·4375	$\frac{39}{64}$	·6093	$\frac{25}{32}$	·78125	$\frac{61}{64}$	·9531
$\frac{7}{64}$	·1093	$\frac{9}{32}$	·28125	$\frac{29}{64}$	·4531	$\frac{5}{8}$	·625	$\frac{51}{64}$	·7968	$\frac{31}{32}$	·96875
$\frac{1}{8}$	·125	$\frac{19}{64}$	·2968	$\frac{15}{32}$	·46875	$\frac{41}{64}$	·6406	$\frac{13}{16}$	·8125	$\frac{63}{64}$	·9843
$\frac{9}{64}$	·1406	$\frac{5}{16}$	·3125	$\frac{31}{64}$	·4843	$\frac{21}{32}$	·65625	$\frac{53}{64}$	·8281	1	1·0
$\frac{5}{32}$	·15625	$\frac{21}{64}$	·3281	$\frac{1}{2}$	·5	$\frac{43}{64}$	·6718	$\frac{27}{32}$	·84375	–	—
$\frac{11}{64}$	·1718	$\frac{11}{32}$	·34375	$\frac{33}{64}$	·5156	$\frac{11}{16}$	·6875	$\frac{55}{64}$	·8593	–	—

CHAPTER VII

TEMPLETS AND JIGS

In chapter IX, the use of templets is mentioned as alternative to the methods of lining off upon the table. Templets, or templates, and jigs are only used for repetitive standard work.

Work is either partially, or wholly, lined out by means of templets, according to circumstances. Thus, the bolt holes in a cylinder flange and cover are very commonly marked, or drilled, from a single templet, after the flange and covers have been turned; or the hole in a solid bearing can be marked from a templet, after the foot has been planed. On the other hand, a cheek or standard, or other similar casting, having a number of shaft bearing holes in it that must have a definite relation to one another and to the foot, will not as a rule be machined at all anywhere until the templet has been tried on, and the mutual relations of all the parts settled, in order to average approximately the amounts necessary for machining. Then, again, there are templets which are properly gauges, being of the same forms and dimensions as the work which has to be done by their aid, and their dimensions are simply transferred with calipers and gauges of various forms to the work.

These concern the marker out, but their preparation is the work of the fitter. Some of those illustrated are made

use of at the lining off table, some at the machines, but in either case they have to pass through the hands of the fitter.

Drilling templets.—If a templet is only used occasionally, and for mere lining out, then for cheapness it may be made of a bit of sheet iron simply, and set upon the flange by the outer edges. This is a common practice in the drilling of flanges for steam pipes, both when they occur on cylinder and condenser castings, and also for the wrought or cast-iron flanges used for screwing upon wrought-iron piping, and also the brazing metal flanges brazed upon copper tubing. Fig. 105 shows two

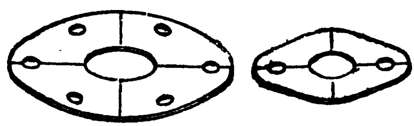


FIG. 105
Sheet-Iron Templets for Flanges.

of these thin templets. One is circular, the other gland-shaped. The holes are marked through the templets, which are then removed, the circles and centres centre popped, and the drilling done.

Fig. 106 shows a templet used for drilling the holes in the flange and cover of a steam chest. As the edges of these parts are not usually machined, the templet is set—not by the edges, but by its centre lines, *a b*, set upon or against the horizontal and vertical centre lines scribed upon the castings upon the marking-off table. Such a templet as this should be of about $\frac{3}{4}$ in. or $\frac{7}{8}$ in. thickness, and of cast iron. Or it may be of sheet iron, of from about 10 to 14 gauge, like Fig. 105.

Sheet-metal templets form a large and important type.

A few examples are given in Figs. 107 to 114. They are made of sheet iron, steel, zinc, or brass, varying from,

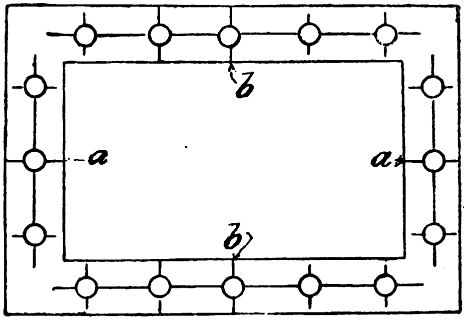


FIG. 106
Sheet-Iron Templet for Flanges.

say, $\frac{1}{32}$ in. to $\frac{1}{8}$ in. thick, according to size and rigidity required.

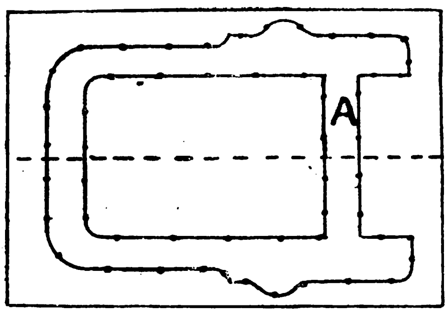


FIG. 107
Sheet-Metal Templet Lined out.

Fig. 107 shows a templet use for lining off a strap for a connecting rod end. This is made of thin sheet iron, and is prevented from opening out by means of the cross-bar A, either riveted upon it, or cut from the solid sheet,

as shown. The figure shows the templet struck out, and its outlines centre popped upon a sheet of metal in readiness for cutting out. The next figure, 108, also shows a templet of a slot link marked out and popped upon a piece of sheet metal.

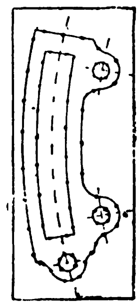


Fig. 108
Sheet-Metal Templet Lined Out.

Thin templets of this kind are roughed out with hammer and chisel upon a block of iron, and finished by filing in the bench vice. If, however, their thickness is considerable, say, $\frac{1}{8}$ in. or over, it is better to drill small holes adjacent to each other, and to the edges that have to be filed, because there is then no risk of distortion occurring, as there is when the chisel is used with considerable force.

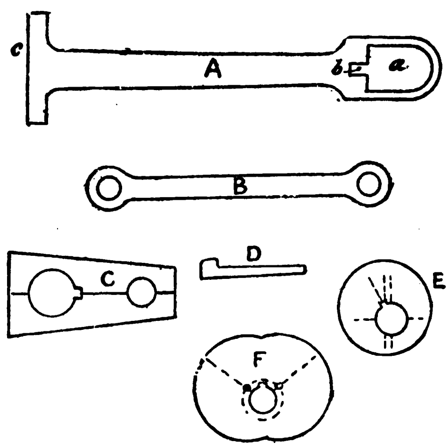


Fig. 109
Group of Sheet-Metal Templets.

Sheet-metal templets are employed for marking out all kinds of outlines and holes. Fig. 109 illustrates a group

of them. A, in the figure, shows one suitable for marking the recess *a* for the brasses, and *b* for the taper-screw key at the small end of a connecting rod; and the flat end *c* to receive the marine-pattern brasses used in the example. B shows a templet for a common double-ended lever. Two circular holes for crank shaft and crank pin respectively, with the shaft key-way, can be marked from a templet like C. D is a templet for marking off a number of keys

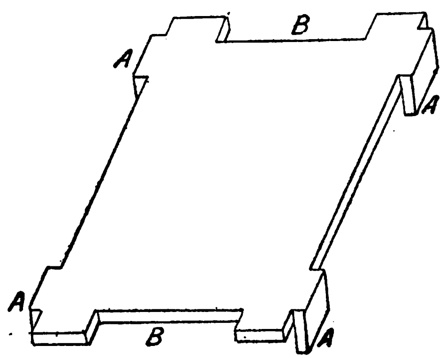


FIG. 110
Sheet-Metal Templet with Guides.

precisely alike; E is one for lining off single eccentric sheaves, the circumference, hole, and key-way in correct positions, while F is for double eccentrics.

Templets like F are not much used for lining out, the turning of these sheaves being usually done upon blocks having the requisite amount of eccentricity given to them, and the key-way cut upon a chucking pin. The only use of the templet, then, is the fixing the position of the hole for boring, and that of the key-way.

Fig. 110 shows a modified form of sheet-metal templet, in which pieces A, turned down at sides or ends, are made

to embrace sides of work already faced, and thus become a guide to the marking off of lines upon a face at right angles therewith. Such a templet as that in the figure is suitable for marking off an engine crosshead, sliding on guide bars of rectangular section. The templet being laid against the end of the crosshead, and the nibs A embracing sides already faced, the sliding faces and edges of the crosshead are marked from the recesses B B.

Fig. 111 shows a templet by which the cottar-way in the stub ends of connecting rods can be marked. The templet

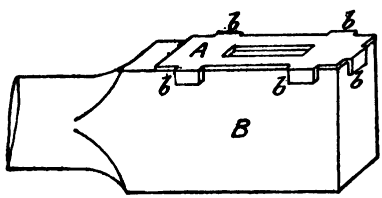


FIG. 111
Sheet-Metal Templet with Guides

A is set on the faced sides and ends of B by means of the nibs *b*, and the hole *a* scribed through.

Thin sheet metal, or cast templets of the general type, shown in Figs. 105 to 111, are of use for a multiplicity of purposes. There is, practically, no limit to their uses, and to the forms imparted to them. Where standard work is being constantly repeated, and centres, distances, and diameters are fixed once for all, the templet is made accordingly, and remains a permanent record of work done, and a guide for future work, and is one of the primary elements in producing interchangeability of parts.

Fig. 112, A, is an example of a templet of another class. It is set to a centre line. This particular one is used for marking the sunk key-ways on a turned shaft. It is a

piece of thin sheet iron, hammered or rolled to the curve of the shaft, and cut to a definite length to correspond with a definite turned length on the shaft. The slots *a a* are cut to correspond with the exact positions of

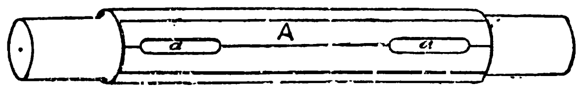


FIG. 112

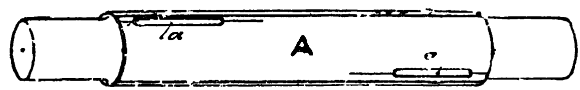


FIG. 113
Templets for Shaft Key-ways.

the key-ways required. So that on laying the templet upon the shaft, the positions of the key-ways can be marked, without putting the shaft upon the lining-off table at all. Also, if key-ways are wanted at angles of 90° for cranks or eccentrics, or at any other angle, they can be so

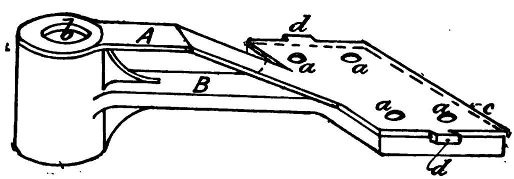


FIG. 114
Templet for Marking Holes in Different Planes.

cut in the templet A, Fig. 113 *a*, *a*, saving the trouble of lining off.

Fig. 114, A, illustrates a sheet-metal templet, used for marking off holes in two distinct planes—namely, the bolt holes *a*, in the foot of the casting B, and the shaft hole *b*. The templet is flanged down at *c* and at *d*, and is thus set in position in relation to the foot.

But all these, though in the most common use, are of the simplest possible types. They are essentially templets for use in horizontal planes only. When centres and dimensions have to be marked out upon more than one plane, templets or jigs can usually be devised of forms suitable to the requirements of each individual case. Frequently a single templet will suffice for a piece of work, sometimes two or more distinct templets are necessary to complete the lining out.

Fig. 115 shows a drilling jig, A, used for drilling the holes, either in a cylinder flange, or in a cover, B. The edges of such covers are usually turned for good appearance, and the turned edge affords an excellent guide for the concentric setting of the templet. Three nibs, *a*, are cast upon its edge, and bored to fit closely to the edges of the turned cover, or flange. The bolt holes may be lined off merely from such a templet, or may be drilled directly through it. The latter is the usual practice, and the templet is then made of cast iron of $\frac{3}{4}$ in. or 1 in. thickness, and if in very constant use, the holes are lined with bushes of hardened steel, *b*; otherwise the holes in the comparatively soft cast iron would soon become worn out of truth by the friction of the drill.

When a cast-iron jig like that in Fig. 115 is used, it is clamped upon its cover with two or three of the screw clamps shown in Fig. 217, p. 250. It is not necessarily used upon the corresponding cylinder flange. It frequently is, however, being set correctly by means of its centre lines, *c* and *d*, so that the cover may stand in its right position. But, as often, the practice is, after the cover has been drilled, to set and clamp that upon the cylinder flange, and to drill the holes in the flange through those already drilled in the cover. When bolts are used, this is the

better way; if studs are employed—the holes in the flange being small for tapping, and those in the cover being large for clearing—the former is the better method.

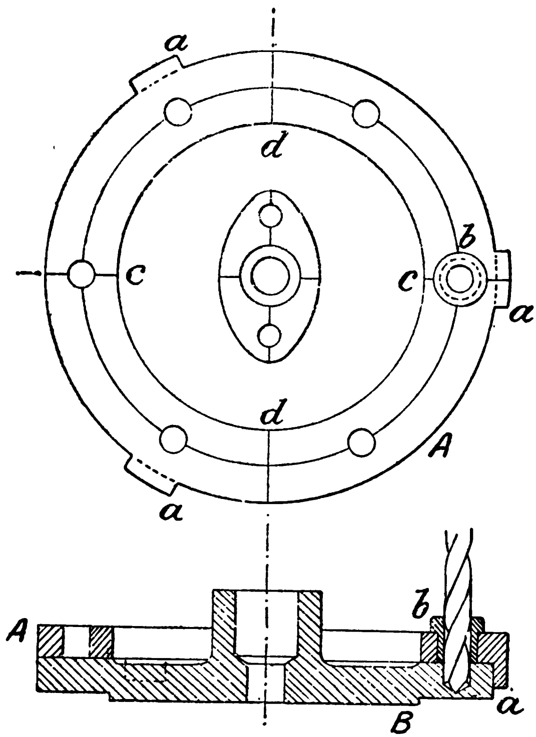


FIG. 115
Drilling Jig.

Fig. 116 illustrates a simple templet or jig, A, used for marking off or drilling the bearing hole *a*, in the dead eye bearing B, and the bolt holes *b* also. Of course, before the templet can be used, the foot must be first planed

along the line *c*. But a rough lining out of that, so as to

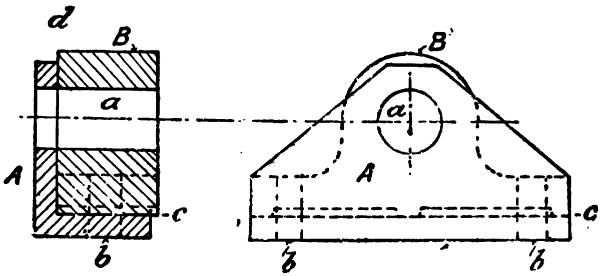


Fig. 116
Jig for Drilling Holes in Dead-Eye Bearing.

ensure the proper height of the centre of the hole *a*, with due allowance all round for boring, is quickly done.

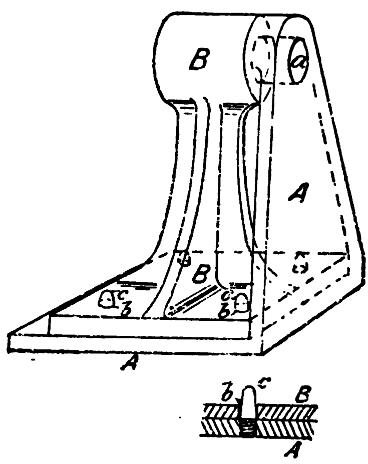


Fig. 117
Drilling Jig for Bracket Casting.

Perhaps also the face *d* may have to be planed, or a circular facing piece only may be faced over, to save

the labour of tooling the whole surface. If so, that must be done also. Then when both foot and face are prepared, the templet is laid on, as seen in the figure, and the holes scribed off or drilled in succession in the castings. In this way many scores or hundreds of similar bearings can be turned out all exactly alike.

The next illustration, Fig. 117, is that of a jig, A, used for drilling the hole *a* in the bracket casting B. The foot of the bracket has been already planed, and the holes *b* drilled by a plain templet of sheet metal or of cast iron, and these now are made the guides from which the hole *a* is scribed or drilled direct. There are four pins, *c*, in the planed foot of A, which correspond exactly with, and enter the drilled holes *b* in the foot, and so fix the position of the templet. A pin is shown in section below the main figure. This is typical of a very extensive and widely varied class of templets used for machining and drilling.

Fig. 118 illustrates a bracket having sundry bearings and bosses for shafts, and Fig. 119 shows a jig, by means of which the bearings and holes may be bored without any lining out. There are several points about this type of jig that should be noticed in detail.

In Fig. 118, A is the bracket foot which has to be planed, B and C are shaft bearings for mitre wheels, D is a lug to carry a pin, E is a boss with a pin hole. The important bearings are B and C, and these have to stand at right angles with each other upon the same centre line, and at a definite distance from the planed foot. To line out these upon the table, two settings at right angles with each other would be required. Using a jig, no lining out at all would be necessary, except a rough determination of the amount to be planed off the foot, and the scribing

of lines round to plane it by. The jig would be the guide for most of the tooling. In Fig. 119 the jig is seen to consist of plates and angle irons, with sundry bored bosses fastened to the plates, at the centres for boring the bearing and pin holes. In the figure there are

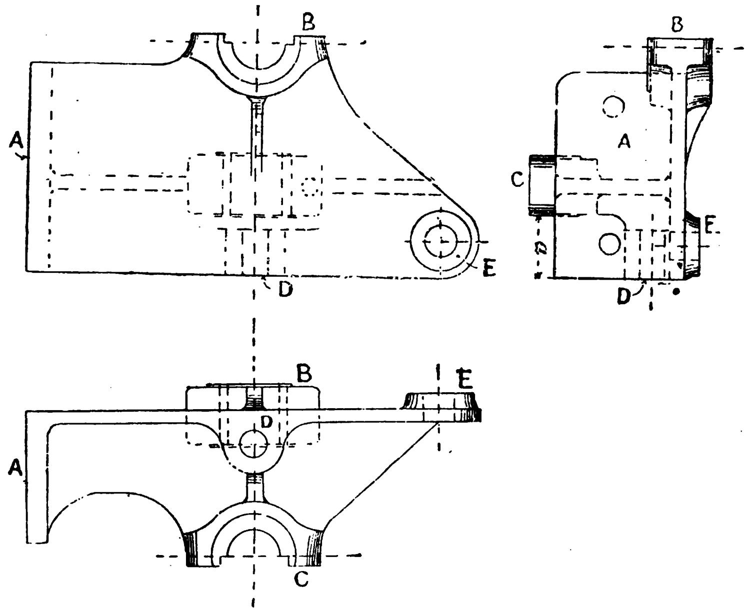


FIG. 118
Bracket Casting.

three pieces of plate, A, B, C, of a thickness suited to the size of the jig usually ranging between $\frac{1}{8}$ in. and $\frac{1}{4}$ in. These are united with angles D, E, F; D uniting A to B, E uniting B to C, and F uniting A to C. These angles are from 1 in. to $1\frac{1}{4}$ in. in width, and are fastened with rivets to the plates, the rivets being countersunk

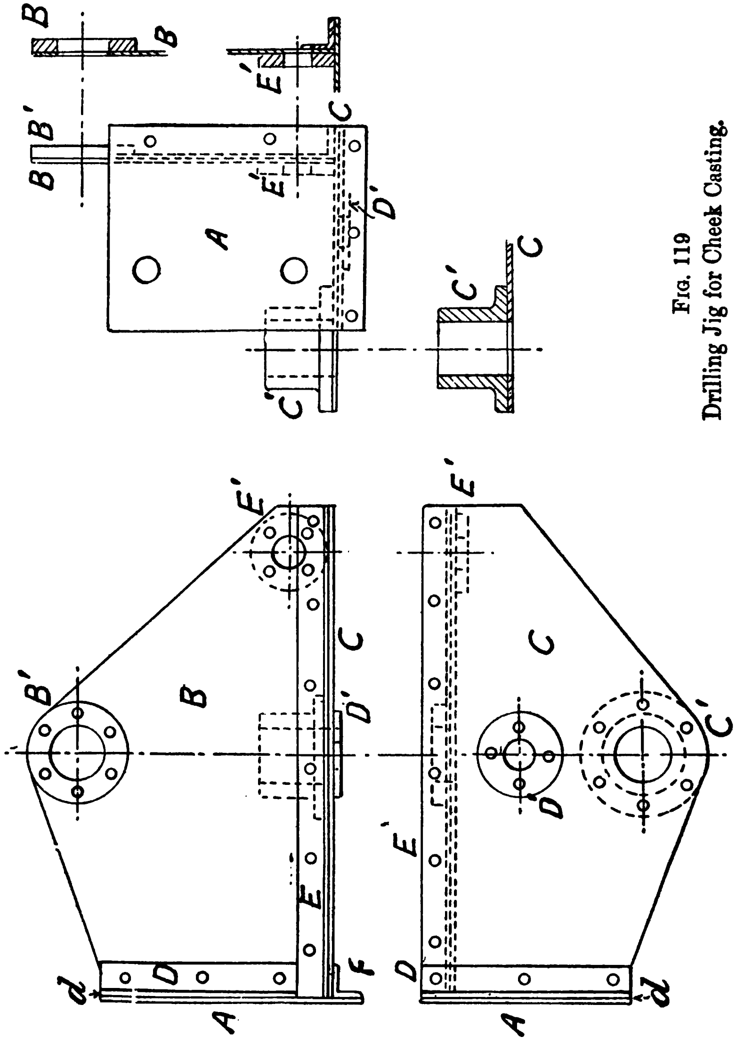


FIG. 119
Drilling Jig for Cheek Casting.

on the faces that go against the casting. The plates are not only united by this means, but being thin, they are further stiffened by the angles, and so rendered amply rigid enough for their purpose. By means of plates and angles, jigs of many diversified forms can be built up.

In Fig. 119 the face *d* of the plate A is clamped against the face of the foot A in Fig. 118. Then the bored boss B′ is the guide for *boring* the bearing B in Fig. 118, the boss C′ for boring the bearing C, the boss D′ for the lug D, and the boss E′ for the boss E.

Note that I use the term *boring*, and also that the bosses have circular holes instead of the proper bearing shapes shown in Fig. 118 for cap and brass. This is done in order to permit reamers to be used in the drilling machine. These reamers exactly fit the holes bored in the bosses of the jig, and are guided and coerced truly by means of these holes. Reamers are therefore used, not only in the plain circular holes, but also in the semicircular seatings for the brasses. Before, however, the last named are broached or reamered, the caps are fitted in by slotting or shaping, and being screwed down in place, the cap and bearing are reamered out together through the bosses B′ and C′ in Fig. 119.

Note also, that the bosses of the jig are of different lengths. Merely as guides to the reamer, they need not exceed $\frac{1}{2}$ in. or $\frac{3}{4}$ in. in thickness, as in B′. In cases where they are thicker, as at C′, the increased thickness is given in order to bring the faces of the boring bosses up close to the faces of the bearings on which they are used. Thus, the thickness of the boring boss C′ in Fig. 119 is equal to the distance *a* in Fig. 118. Further, the boring bosses B′ and E′, Fig. 119, are placed on opposite sides of the plate B, to suit the different horizontal planes of the bearing B

and the boss E. So that when the templet is laid on the casting ready for use, each boring boss is in actual contact with the face of the bearing, or of the boss, for which it becomes the guide to boring.

The thinner bosses, like B′ D′ E′, are simple rings of wrought iron riveted upon their plates; thick bosses like C′ are flanged castings, riveted through the flanges to the plates.

Fig. 120 shows a jig suitable for machining a cheek or bracket like that shown in Fig. 132, p. 145, without previous lining out. It is of a different class from that shown in Fig. 119. For when templets, or jigs, of large size are employed, they are not made of solid plate, but are built up with narrow strips of sheet iron riveted together. Jigs of large dimensions, even though made of thin plate, would be cumbrous and awkward to handle. So that these are invariably made of narrow strips, riveted together. The figure, then, illustrates one of this class. There is nothing special to be noted in regard to the arrangement of the strips. Rigidity is the main essential, and the strips are therefore disposed with a view to insure the utmost rigidity combined with the minimum of weight.

In the figure, the bottom plates A A, and the top ones, B B, are double; the end ones, C and D, are single. These form the main framework of the jig. The single plates pass between the ends of the double ones, and are riveted through, with rivets countersunk on both faces. The only portion of this framework that corresponds with any part of the casting is the bottom edge of A A, and the ends of the same, which coincide with the bottom and ends of the casting. The portions E and F that correspond with the bearings, are made each in three thicknesses, riveted to each other, and to the main frame. The middle thick-

ness of **E** passes between the pieces **A**, and the side thick-

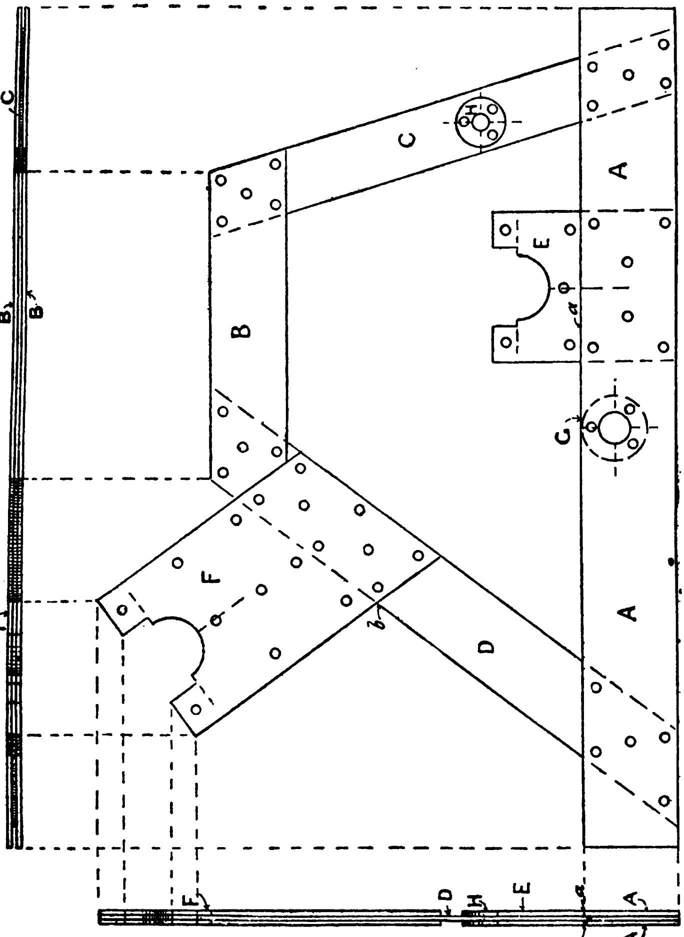


FIG. 120
Jig for Cheek Casting.

nesses terminate at *a*, making a close joint for the sake of

firmness. The middle thickness of F, on the contrary, abuts against D at *b*, and the side thicknesses pass across each face of D, and are riveted through it. Bosses, G and H, are riveted respectively between and on the plates to guide the driller, or for the purpose of marking the holes only.

This jig, like Fig. 119, is typical of a large class made for cheeks and frames of various forms. It is easy to scheme the framework. In this particular example all faces are flush, but it will often happen that some faces have to stand in a different plane from others, as in the previous example. Then bosses or extra thickness pieces will be put round those bearings, the faces of which are lower than others. For large frames several cross bracings, not needed in the example given, may be required. And it is better to build up a large templet or jig, with light strips well braced, than to use heavy scantlings not braced, for these are of considerable weight, and have mostly to be lifted by hand labour.

In this example the bearing seatings in the jig are cut out to the precise form of the machined casting, instead of being circular, like the previous one. Using a templet of this kind, the bearings are not drilled under a drilling machine, as in Fig. 119, but are bored on a boring machine with a horizontal boring bar and cutters. The bearings, therefore, are lined out from the templet, the cap seatings machined, the caps fitted in, the bearing circles completed on the caps, the cheeks bolted to the bed of the boring mill in pairs, or in several sets at once, and bored through.

There is a large class of templets of quite a different character from those just described. They are, however, more of the nature of gauges than of templets proper, and scarcely come within the scope of "Fitting." They are for

the most part finished sections of work, kept as permanent guides and records of standard work. Thus a standard pin will be kept as a permanent gauge to make other pins by, using it simply for the transference of dimensions to the new work. Standard glands, spindles, axles, connecting-rod ends, collars, short lengths of male and female screws, rod gauges, and caliper gauges for boring and turning, fixed trammels—and so forth are kept for standard work. They are essentially duplicates, and therefore scarcely come within the scope of our subject.

CHAPTER VIII

MATERIALS

THE materials with which the fitter has to work are invariably the common metals and their alloys. These, however, occur in such diverse grades that the fitter has to learn by experience their several qualities and the modes of treatment suitable to each, until he knows them almost as if by intuition. These materials are cast iron, wrought iron, the steels, gun metal, and the numerous brasses, and bronze alloys.

Cast iron.—This is used when mass and rigidity are required, or when intricate forms are wanted, even though the work is relatively light. Wrought iron is used for light rods and parts where elasticity is an advantage, and where greater elastic strength is obtainable than in cast iron of similar section. Steel is employed for similar purposes; but its greater rigidity and strength permit equal strength to be obtained with slighter proportions (a most important consideration in many instances), and also for tools. Gun metal and the bronze and aluminium alloys, and white metals, are used for bearings of many kinds, and for light castings, for which cast iron would not have sufficient toughness, and which would yet be too intricate to be forged or stamped. In time, fitters learn to distinguish between different qualities of metal by the way in which they work, or by the appearance of fractured

surfaces, but a good deal of experience is required to be able to do so.

Cast iron is used more extensively than any other material in the average run of engineering construction. There are several reasons for this. It is easily cast into forms the most intricate; it is very strong for structures or parts of structures which are subject to compressive stress only; it is very rigid, possessing, so far as all practical purposes are concerned, neither elasticity nor ductility, and taking no permanent set. It is very readily tooled, and its bearing surfaces, when large, wear excellently; it is obtainable in many grades—soft and open-grained, or hard and capable of taking a surface as hard as steel, and also in all intermediate conditions; lastly, it is very much cheaper than any other metal. But on the other hand, cast iron is very weak in tension—so weak that in cases when tensile stresses are severe and alternating, and in live loads, few engineers will use cast iron at all. Further, in many structures or framings where lightness of scantling is important, cast iron does not afford the necessary strength consistent with the lightness required. Again, being relatively soft, it rapidly wears if subject to excessive friction on narrow surfaces—in gear-wheel teeth, for example—and then a harder material which will nevertheless cast well, must be sought.

The typical grades of cast iron are the *white, mottled,* and *grey.* Between these there are intermediate qualities. Although the determination of these intermediate grades is not always easy, there is no mistaking the appearances of the broad types themselves. Though the quality of iron can be very roughly judged by the way in which it can be chipped, filed, and turned, the only way in which an accurate judgment can be formed is by noting the

aspect of a fractured surface. The testing by machine is, of course, not a method available at the work bench; neither is the method of judging by fracture always available. Still, where pieces are chipped off, or where parts have been broken by accident, or where runner ends have not been ground off, there is often sufficient surface left to enable the fitter to form a fairly correct judgment. The fracture of white iron is always of an almost silvery whiteness, and the crystals are arranged in long, needle-like bundles. Chilled iron has the same appearance. Grey iron, on the contrary, is of a bluish-grey colour. The poorer the iron, the more dull the appearance of the crystals; the stronger the iron, the brighter and more metallic-like the hue. The crystals of this grade are not needle-like, but rudely rectangular or prismatic in appearance. In poor iron they are coarser than in that of better quality. But their size depends mainly on the mass of the metal in which they occur. In small sections they are invariably of small size; in large masses invariably large, because they form more slowly in the latter case than in the former. In large masses of metal, the crystals are of irregular size—small near the surfaces, larger as they approach the centre. In grey iron, the particles of graphite can be distinguished by shading the specimen with the hand from the direct action of the light. The graphite will appear in patches darker than the other portions. It is mechanically intermixed with the mass. This is the class of iron used for all general jobbing work, for standards, plates of all kinds, castings where mass is the chief requisite, brackets, plummer blocks, and such like. It is only moderately strong, but is very easily worked, and is used more than any other kind.

The mottled iron is a *strong* iron, combining the best qualities of the grey and of the white types. The characteristic *mottle* is caused by the intermixture of the silvery crystals of the white with the graphitic carbon and crystals of the grey. Thus it will be seen that different specimens of iron will contain the mottle in a greater or less degree, according as one or the other grade predominates. The designation "mottled" iron is therefore a very elastic one. But, speaking generally, it is tough and strong, is durable and wears well, and is tooled without special difficulty. It is used in all the best work—in engine cylinders and liners, hydraulic work, guide bars, cross heads, and air vessels, in toothed gearing, and for anything where great shock and stress or much friction are encountered.

For ordinary engineers' work, iron must be sufficiently *soft* to be tooled. White iron is so hard that it can only be worked by grinding, or very slowly by scraping tools. It has its special uses; but for our purpose it may be disregarded. In ninety-nine cases out of a hundred, soft iron, meaning by that, iron workable by cutting tools, is required. But "soft," again, is a vague term; some metal is so soft that it works dirty and dusty, owing to the presence of a large proportion of uncombined carbon. Though it is nice to have iron that can be cut and filed so freely, it is objectionable, because of the want of durability. Iron so soft is unfit for wearing faces, such as those of machine or engine slides, the bores of cylinders and journals. It is rapidly abraded by friction, and consequently wears out too soon. For such purposes, the iron must be tough and close grained, and mottled; and this does not tool so freely as the other. Yet it can be cut with sufficient readiness, and is strong, which the

other is not. It is fortunate that mottled iron can be mixed in several grades. Thus a cylinder liner is made of tougher, smoother, or more *greasy* metal than the casing, and generally the greater the stress and wear upon a part, the nearer the metal is made to approximate to the extreme mottle—that is, towards the white quality. The fitter finds out these differences by experience, learns how to treat each kind of metal to the best advantage, both as regards facility of cutting and care in handling. For cast iron is treacherous. Many a time a foreman has to replace castings, partly or wholly machined, in consequence of the fracture of inherently weak parts; parts, however, that were strong enough for their functions if treated carefully. A slight tap of the hammer will break off a lug; forcing a tap will split a small boss; pinching a bolt too tightly will fracture a flange, and so on. Cast iron in mass is strong, but all little projections and thin parts are weak. All the more reason why due allowance should be made for these things, and care be taken to prevent mishap. For it must be remembered that in many cases it is only during fitting that fracture is likely to occur. When a mechanism is finished, and the parts are all jointed and fastened together, face to face, there is little or no risk of fracture happening until the time comes for taking the mechanism apart for alterations and repairs.

Wrought iron.—In this material, high tensile strength is combined with lightness of scantling. It is highly ductile, elastic, and takes considerable permanent set. But it cannot be worked cheaply into intricate forms, is not so serviceable in compression as in tension, is not quite so readily tooled as cast iron, does not stand frictional contact well, and is not cheap. Intricate forgings are

costly. Likewise all wrought iron except the very best (which is double the price of average quality) labours under the grave disadvantage of being very liable to hidden defects—seams of dirt, scale, laminations, and cavities in the heart of large forgings. Unless, also, care is taken in the formation of forgings, the fibre in some parts which have to stand tensile stresses may be arranged in the weakest manner. And with the rapid increase in the dimensions of engineer's work which has been going on during fifteen or twenty years past, the evils inherent in wrought iron in large masses have caused engineers to discard it almost completely for heavy work. Good wrought iron should not only show metallic lustre, but should be free from cracks. In inferior material, cracks, often of a large size, occur in the direction of rolling. When large, they are obvious on cutting the bar; when small, they may be seen black by contrast with the red or white heats of the forge. A fitter should, before spending much time in forged work, always endeavour to note if scale, and cracks, and imperfect welds are present in any vital parts. These are often hidden and invisible until a portion of the outer skin has been removed by chipping or machining. The larger the forgings, the more apt these defects are to occur, especially about the central portions. Another important point is that the fibre of the iron should be disposed in the direction where greatest strength is wanted. The plane of the layers of iron should always be disposed at right angles with the line of greatest stress. Short fibre should not occur in an inherently weak part, but the metal should be bent round continuously. A fitter can generally note the direction of fibre on a surface brightened by filing.

With wrought iron risks of fracture are very much less

than in cast iron. This material seldom snaps off without giving warning by bending. And, further, although there is a vast deal of difference in different qualities of wrought iron at the forge and testing machine, there is practically no difference at the vice. It is always easier to file wrought than cast iron, the file hanging well to it, instead of slipping, as it will on tough cast iron. It is more easily chipped also, the chisel not striking off so readily as from cast metal. The quality of a wrought iron is judged better at the anvil than at the vice. But a good piece of forged iron should show a bright metallic lustre. Dull iron is always poor in quality. When a broken piece of wrought iron shows a highly crystalline surface, that merely proves that it was fractured by a sharp blow. The most fibrous material, when nicked and broken suddenly, will show a highly crystalline surface, not much unlike cast iron; but if bent and fractured by gentle hammering, or if torn asunder slowly, the iron, even though poor, will show a silky, fibrous condition. Hence the way to judge of wrought iron is by its metallic lustre, and by its behaviour under the hammer.

Cast steel.—Steel, in the form of castings, or rolled from open-hearth or Bessemer ingots, is free from many of the objections to which both cast and wrought iron are open.

Cast steel is strong, both in tension and compression; and by slightly varying the chemical composition, castings of extreme hardness, or relatively soft yet strong, can be supplied. For the successful casting of steel much care and experience are necessary. I have seen a good deal of steel castings of all grades—at their worst and best; some honeycombed with blow holes, so hard that they could scarcely be tooled—drawn, cracked, lumpy. Others

as sound and clean as a good iron casting—lustrous, tough, but readily tooled, free from draws and cracks and lumps. If a good price is given to a good firm, steel castings can now be obtained which leave nothing to be desired.

Steel, however, as far as our present knowledge goes, is not likely to supersede cast iron for every kind of work. There are many castings for which it cannot be depended upon. It shrinks so much in cooling, and so variably, and draws so much, that it is not suitable for castings of disproportioned forms, because the heavier portions shrink so greatly that the heavier masses pull away from the lighter, and either produce flaws, or warp the casting out of truth. The steel founders often insert large radii in certain parts, solely to prevent a casting from becoming broken in those localities. It is impossible to cast wheels with heavy bosses, and with arms and light rims, circular, the boss and arms pulling the rim inwards opposite each arm. Castings with large cores seldom come out flat and true. Neither are frictional surfaces in steel desirable, because they heat and score, so that it is not suitable for those machine or engine parts which are subject to friction. For these reasons, cast steel is not adapted for all classes of castings.

But for gearing, judiciously proportioned, steel is an excellent material. It is also eminently suitable for much light work for which cast iron is not strong enough, or for which a stronger material or lighter section is desirable, and for work for which the only alternative is forgings. For these classes of work steel is suited capitally. I need only instance horn blocks and axle slides, wheel centres, dies, or stamps, levers of many types, connecting rods, rollers, etc.

Mild steel.—This material is not very different from

wrought iron, except that it is harder, more rigid, stronger and tougher. But mild steel includes many different grades, and some of them are very intractable and difficult to cut; others, again, are nearly as soft as forged steel. Good steel should show a silvery fracture and fine grain; coarse grain is a mark of inferiority. It is, however, in working at the forge that the quality of steel is best determined.

Tool steel.—Temper steel, or high carbon steel, is a material of varied composition, used chiefly for cutting tools. It contains considerably more carbon in its composition than the mild steels, and its qualities vary so extensively that each grade of temper steel seems to require humouring by the smith in some way or another different from other qualities. The weight of tool steel used in a large factory is heavy, at prices ranging, say, from 6*d.* to 1*s.* per pound. Hence one reason why the use of tool points in tool holders has extended so much in large firms.

Malleable cast iron.—The cheapness of casting by comparison with that of forging has been one reason for the very extensive use of cast iron, even for work for which experience has demonstrated its unsuitability. This is one reason, also, why malleable cast iron has been employed to a considerable extent in place of cast iron. But malleable cast iron, though an excellent material for some work, is ill adapted for engineers' use, in which strength and reliability are required. It is well adapted for large classes of ironmongers' light castings, but not for parts of machinery. It is liable to crack, is not strong, and cannot be employed for any but very small articles. Still it is used to a limited extent, and will probably continue to be so used. But two classes of work are running it very

close—light steel castings and drop forgings. These, though more costly, are in all respects superior to malleable cast iron. Extreme toughness can be obtained in steel castings by the process of annealing, and extreme surface hardness with interior toughness can be obtained in forgings by case-hardening.

Copper.—The applications of copper used alone are not so extensive as those of the copper alloys. It is used for pump rods, steam pipes, fireboxes, and stays chiefly. But alloyed with tin it forms the gun-metal bearings for machinery, and this, with phosphorus, forms the phosphor bronze. It is the basis of Delta metal, Muntz metal, aluminium bronze, and other alloys, and of the hard and spelter solders.

Gun metal and brass alloys.—These occur in all possible grades. But the chief point common to all is that they are homogeneous. Whatever the proportions of their components, the metals should be so well mixed that the cutting tools shall not be able to detect harder and softer spots. If gun metal is hard, it should be uniformly hard; if soft, it should be soft throughout. That is about all that can be said from the fitter's point of view.

The engineer has thus a splendid range of choice of metals and alloys for all conceivable purposes. Chemistry is his handmaid, teaching him the reasons why; or, if not the ultimate reasons, the knowledge that certain proportions of certain elements will produce certain definite results in the metals and alloys. Strictly speaking, all the metals used in engineering are alloys. Pure iron or pure copper is never used; but carbon, manganese, silicon, and other elements make the differences in qualities. In many instances the aim is to arrive as near to absolute purity as possible. That is the aim in wrought iron and

copper; in others, it is not to obtain a pure product, but one with certain exact proportions of other elements intermixed, and that is always the aim in the steels and cast irons, and in the copper alloys. By judicious blending of elements, extreme hardness or considerable softness are obtained, rigidity or ductility, malleability, high temper, or ease of cutting.

Friction of materials.—It is often the case that there is a great deal of wear on certain axles, bearings, or other moving or sliding parts; and perhaps a steel spindle or a steel face is inserted with a view to obtaining increased durability. But the result is more rapid wear; for the steel spindle and steel faces in mutual contact score and cut their opposed faces at a rapid rate. Cast steel on cast steel is the worst possible material to be brought into contact; forged steel is nearly as bad. Steel will also cut and score cast iron in a less degree; but cast or forged steel will work well in contact with gun metal or with white metal; therefore, if a steel spindle is used, the bearings must not be of steel, and better not of cast iron, but of gun metal, or some other alloy of copper, or of a white metal, and if faces are in sliding contact, one or other face must be of one of these materials.

Cast iron and cast iron, or cast iron and wrought iron, revolve or slide together with little friction, provided the surfaces are not very narrow, or the speed very high; but with narrow surfaces, and at high speeds, both cast and wrought iron should be in contact either with gun metal or with white metal. White metal must be well supported and enclosed in its bearings, either by being cast into narrow slots, as in some axle bearings, or in holes, as in many large slide valves.

Wood bearings are occasionally used for wrought-iron,

cast-iron, and steel spindles. Many of these are to be found in all old mills for shafting, and when their surfaces have become well saturated and hardened with oil, they wear as long as metal. But the principal use of wood for bearings is for shafts that run in water, such as the vertical shafts of turbines in their steps, and the stern shafts of propeller screws in their tubes. The wood used in these cases is lignum vitæ, which is fitted into suitable recesses cast in step, or stern tube, and the surrounding water is an excellent lubricant.

Lubricants.—The question of the best lubricant to use under given conditions continually arises. The oils and the fats are the principal lubricants. But they exist in all grades, and as the physical conditions under which parts of mechanisms work differ, so must the lubricants chosen differ also. First there are *thick* oils, or oils having much "body," and there are the *thin* oils—that is, oils having little body. A thin oil is better for diminishing friction, but a thick oil lasts longer, not being squeezed out from between the bearings like a thin oil, so that a thin oil will not answer at all for heavy shaftings or sliding faces, for which a thick oil must invariably be used. The mineral oils are thin, and so are lard, olive, and sperm oils. Castor oil, neatsfoot, tallow, and rape are thick. For high-speed bearings and light spindles or shafts there is nothing better than sperm oil, but it is costly. For heavy bearings castor oil is superior to this, but is also expensive.

But there is relatively little pure lubricant used in machinery, for it is usually more economical to employ a compound oil, compounded for special uses, than to use the pure lubricants, which, too, are often heavily adulterated. The chief advantage, however, pertaining to the

use of compound oils is that the objectionable qualities of one kind of lubricant can be neutralized by mixing it with a lubricant of another kind. For instance, vegetable and fish oils are *drying* oils, that is, they oxidize rapidly, and cause gumming or clogging of the bearings to which they are applied, and if suffered to drop and accumulate upon dust, cotton waste, and timber, are liable to cause spontaneous ignition. Further, a mineral oil does not oxidize. But mineral oils have what is termed a *low flashing* point; that is, they fire or ignite at a low temperature, some at 212° Fah., or under. Again animal oils develop fatty acids, and these corrode and pit the metal which they are used to lubricate. A deal of this corrosion is often seen in engine cylinders that have been lubricated with tallow. It is obviously undesirable, therefore, to use a fat for lubrication which will fire at a low temperature, or which will pit the surfaces of wearing parts. And since the pure lubricants are costly, and since good lubricants suitable for all special classes of work can be compounded much more cheaply, the practice is to combine the various kinds of oils and fats in such proportions that their objectionable features shall be neutralized. In this way various qualities of compound oils are prepared to suit all classes of machinery, and nobody knows the composition of a lubricant, but only its commercial name, number, or brand.

The methods of affording lubrication to bearings are very numerous, from the simple oil-cup and hole to the elaborate sight-feed lubricators, impermeators, and the many patented methods. Speaking generally, lubrication should be self acting, the principal types being the needle, acting by capillarity, the tapes, acting also by capillarity, and the sight feed, acting by specific gravity, or steam pressure.

Bearings will often become heated, either by bad fitting, or too tight fitting in the first place, by neglect of proper lubrication, or by too continuous running. If due to either of the first two causes, the parts in contact must be re-scraped until an easy or a sufficiently slack fit be insured. If from the latter causes, water must be poured upon the bearings first, and oil afterwards. But if the bearing is very hot, it must either be allowed to cool down somewhat, or hot water must be first poured upon it. Sulphur is sometimes mixed with the oil.

CHAPTER IX

LINING OUT

Lining out, or marking out work for machinists and fitters, is, in large shops, a special task performed by one man, or by two or three men, dependent on the size of the establishment. In small shops each fitter usually lines out his own work. In standard, and often repeated, work, little or no lining out is done; but the parts are machined by metal templets. It would not do to shape work having several faces and centres, all mutually interdependent, at random. The relations of the several cardinal dimensions must be ascertained before beginning to tool any portion; otherwise, when half the work were done, the discovery would be made that a portion or the whole of the remainder would not hold up to correct dimensions. All work, therefore, except that of special and standard type, which is machined by templets, is lined or marked off before it is shaped to ultimate finished form. The time and trouble of lining off is saved when templets are employed. But templets, being costly, are seldom used, except when a sufficient number of pieces are required precisely alike to justify their expense. So that for nearly all the work of a jobbing shop, the preliminary lining off of castings and forgings is necessary.

Most of the appliances and tools used in lining out are

either shown in the accompanying figures, or are illustrated in other chapters. They consist mainly of the table, the crane, vee, and packing blocks, wedges, surface gauges, squares, calipers, and the necessary straight-edges, rules, compasses, and dividers.

There are certain preliminary matters which lie at the basis of all accurate lining out, and it is as well that we should at the beginning have clear ideas of those fundamentals.

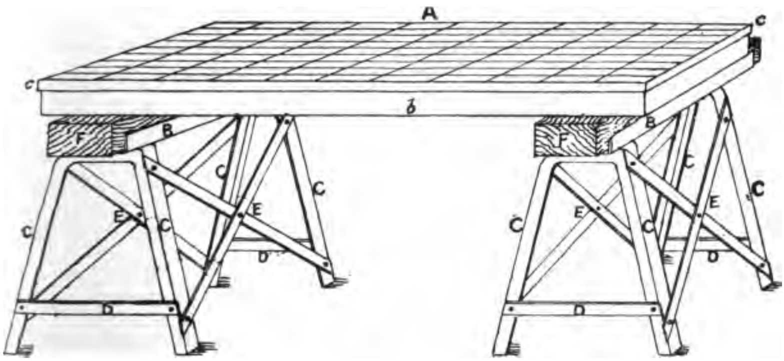


Fig. 121
Marking-off Table.

Marking-off table.—In the first place, the fitter provides an artificial level base, quite distinct from the work itself, from which to mark vertical distances, to set up lines at right angles, and to draw parallel lines in horizontal planes for the purpose of obtaining faces and centres. This is the marking-off table, Fig. 121. The table A is a stout, strongly-ribbed cast-iron plate, planed over upon surface and edges. Its cross section is shown in Fig. 122. It has to be so rigid that it will not spring, and so true that lines

can be squared from its surface and edges. Its size will depend entirely upon the nature of the work done. A useful surface plate generally serviceable for the work of a shop of average size, may measure from 10 ft. to 12 ft. long, by 3 ft. 6 in. or 4 ft. wide, by from $1\frac{1}{2}$ in. to 2 in. thick in the plate, and 6 in. or 7 in. in total depth. The outside ribs *b*, and the transverse ribs *a*, being deep, afford extra rigidity to the plate. The plate is cast with its face downwards to get clean metal there. Two planing cuts—a rough, and a finishing one—will be taken off face and edges. No scraping is necessary. To save the cost of planing the edges throughout the entire depth of the ribs, strips, *c*, equal in depth to the thickness of the table, are

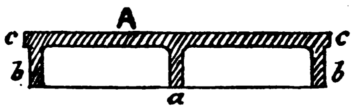


FIG. 122
Section—Marking-off Table.

cast all round and planed. Lines and measurements can be marked from those edges. The surface is often crossed at right angles with fine scribed lines running parallel with each other at convenient distances apart (as shown in the figure), as at every 12 in., or 6 in., or 3 in., or even less; this is convenient, but is sometimes omitted.

The table is supported upon any suitable basis, its surface being about 3 ft. from the ground. Two very stiff wooden trestles, or, better still, two trestles made from channel and angle iron, with hard wood blocking, Fig. 121, are as suitable as anything. A piece of channel iron, B, is cut off, and supported with two legs of angle iron, C, bent as shown. These are stiffened with stretchers, D, and with diagonals, E, of flat bar iron, riveted to them. A

block of wood, F, is fitted into the channel iron to form the top of the trestle.

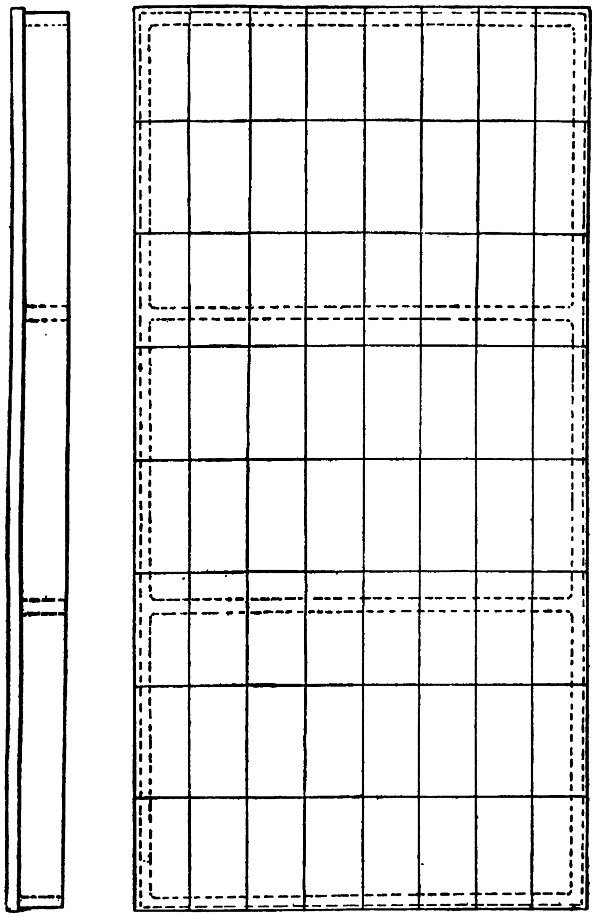


Fig. 123
Marking-off Table.

Fig. 123 shows another typical marking-off table, measuring 8 ft. long. Deep ribs are cast around the sides, and

two lateral ones help to stiffen it. Parallel lines running longitudinally and transversely are used for setting purposes, and for taking points from.

It is necessary that the table shall be clear of walls or machines, so that the workman can get all around it. This table is the sheet anchor of the marker-out. Very seldom are lines set up from the edges of castings or forgings. Even if there are edges already planed true, it is better to set them upon the table, and square up or scribe from the face of the table, rather than to use those edges for squaring or scribing from. There is less risk of error when working from a broad surface than when setting a square, or compass caliper, from a relatively narrow edge or face.

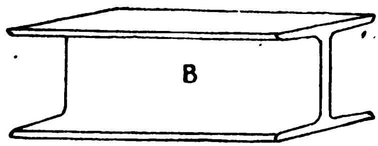
Centre lines.—It is often quite impossible to mark a piece of work out at one setting. But always, before shifting the position of work upon the table for a second or a third lining out, it is essential that centre lines should be made the basis for accurate re-setting. Thus a horizontal line marked with a surface gauge in one position of the work can be set in the vertical direction with a set square, and other lines then marked with the surface gauge in the new position will be at right angles with the vertical line. So also with a vertical line brought into the horizontal position, other verticals then set up with the square will be at right angles with the first. These methods are invariably adopted in preference to setting one edge of a square against a line to mark another at right angles with it. In every case it is the table that is made the basis of lining out.

It is very advantageous, when practicable, to have one face of the work planed truly to lay upon the planed surface of the marking-off table. There is then no risk of the work becoming shifted during the process of marking out. It is, of course, frequently not practicable to start

with a planed face, because of the necessity for tentative lining out in order to secure average allowances for machining. But often a rough lining out is first made, sufficient to settle the position of the planing line for one cardinal face, and then a rough cut is taken off that, so that it may lie truly upon the table before the bulk of the actual lining off is done.

When this is impracticable, or when the work is of an irregular character, the use of blocking-up pieces and wedges has to be adopted.

Vee Block.



Parallel Iron.

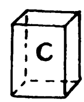


Fig. 124
Packing Block.

Supports and packings.—For supporting such work upon the table, *vee blocks*, Fig. 124, A, *parallel irons* B, *packing*

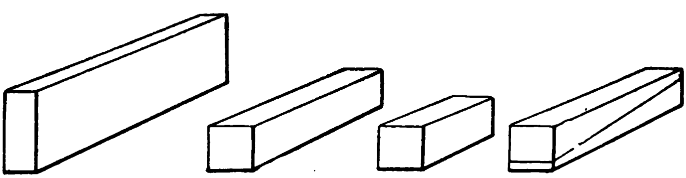


Fig. 125
Packing Strips.

blocks C, and little *iron wedges* are used. The vee blocks are employed chiefly for supporting shafts and circular spindle-like work generally. They are made in cast iron,

in pairs of different sizes, planed both on the bottom and in the vees. The parallel blocks C are also planed all over on each face, and are kept in different thicknesses and lengths. They support and pack up flat surfaces. Very convenient light blocks are made by cutting off suitable lengths of H iron, B, of different sections, and planing the top and bottom faces, ends, and edges. The wedges are used for steadying work laid either upon the table or upon the parallel blocks when the under face of the work

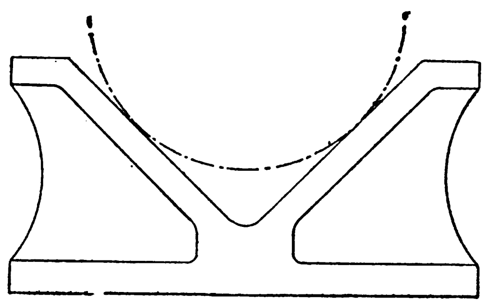


FIG. 126
Vee Block.

in contact with the table, or blocks, is rough and uneven, as in the case of a casting or forging upon which no preliminary machining has been done.

Various parallel packing strips are seen in Fig. 125, the first three of different thicknesses and lengths, and the fourth of double wedge form, which can be slid on each other to effect adjustment in height.

Large vee blocks are cast as in Fig. 126, of ribbed form, for the sake of lightness. Tall vee blocks are raised upon stems, as in Fig. 127. They are used largely on floor-plate work, for erecting. Adjustable vee blocks, useful in

machining and subsequent erection, are made with a screw tail and a lock nut in a cast-iron stand, see Fig. 128.

It is often the case that some lines and centres have to be marked upon portions of the work that stand very far above the range of the scriber point when its base rests upon the table; and yet perhaps it is not convenient or

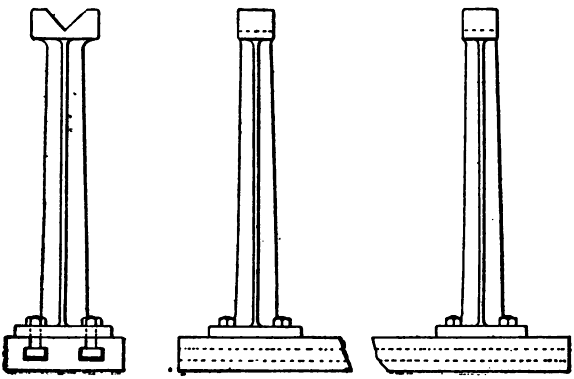


Fig. 127
Tall Vee Blocks.

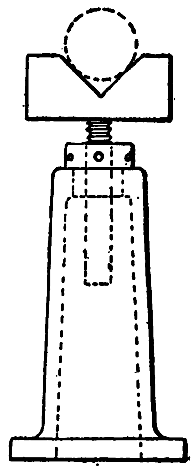


Fig. 128
Adjustable Vee Block.

desirable that the lines or centres should be marked except from the table as a basis. Then the parallel-planed blocks B, Fig. 124, are laid upon the table, and the scriber base is slid along upon them. Blocks of various thicknesses are thus utilized singly or in series to raise the surface gauge sufficiently high to enable the point to scribe the required lines.

The channel irons B, Fig. 124, are used also for marking temporary centres upon for transference to the work.

Thus, if there are centres situated upon faces that do not stand in the same plane, such as A and B in Fig. 129, then these centres are marked upon one face of the channel iron at *a* and *b*—the iron being stood on end upon the table C—and the point of the surface gauge is set to each in succession, and transferred to the faces of the bosses. The other way of marking such centres is by means of trammels with one leg adjustable for vertical

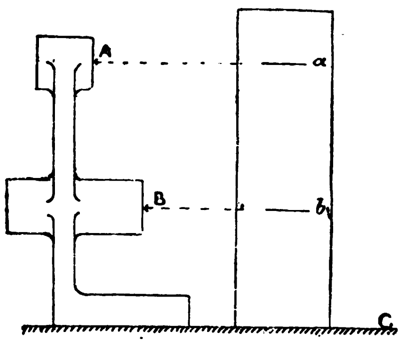


FIG. 129
Transferring Centre Lines with Scribing Block.

height, or with set squares, neither of which is so accurate as the method of direct transference.

Occasionally it is convenient to bolt small pieces of work to an angle plate for lining out. It is so in some light forgings of very irregular form which cannot be packed up, or which, if packed up, would be so light that they would not remain sufficiently steady while being scribed off.

Lines.—Ordinary scribing blocks, or surface gauges (see Chapter VI, p. 77), are in constant request by the marker-out. Without these it would be impossible to line out

work accurately. No matter how irregular the surface of a casting or forging may be, the scriber point will follow round and over it, and mark a line, or any number of lines, exactly parallel with the planed face of the table, over which the base of the scribing block is moved. Also the bent turned-down point of the scriber is used to test by contact the upper surface of a piece of work that requires to be set in a truly horizontal plane. The scriber has, moreover, a considerable amount of vertical range, by virtue of which it is adaptable to work of varying heights. And the length of the scriber and its horizontal range allow it to meet and mark surfaces that stand back and away from the general perpendicular level of the work.

Very exact centres and distances are not set off from the edges of rules, but with dividers, compasses, or trammels. One leg of the dividing instrument is set, not at the end, but in one of the divisions of the rule, usually in the first inch, and the other leg is set to the dimension required. The dimension so obtained is then transferred to the work.

Centre punch.—Two or three centre punches, light and heavy, are always kept at hand. They are made from old round files, or forged from rod. It is better to make the body of hexagonal form, as the tool can be grasped and rotated better in the fingers than if left smooth.

Clearness of definition is essential in lining out work. Lines must be reasonably fine, yet perfectly distinct. To give a good background the practice is either to prepare the surface by chalking, or by brushing it over with a solution of whiting in water, left till dry. Not only are the lines scribed on this, but in case of their partial obliteration two devices are resorted to. One is to centre

pop the lines at intervals of about every half inch, the other is to scribe another line at a little distance outside the actual working line, and parallel with it, and centre

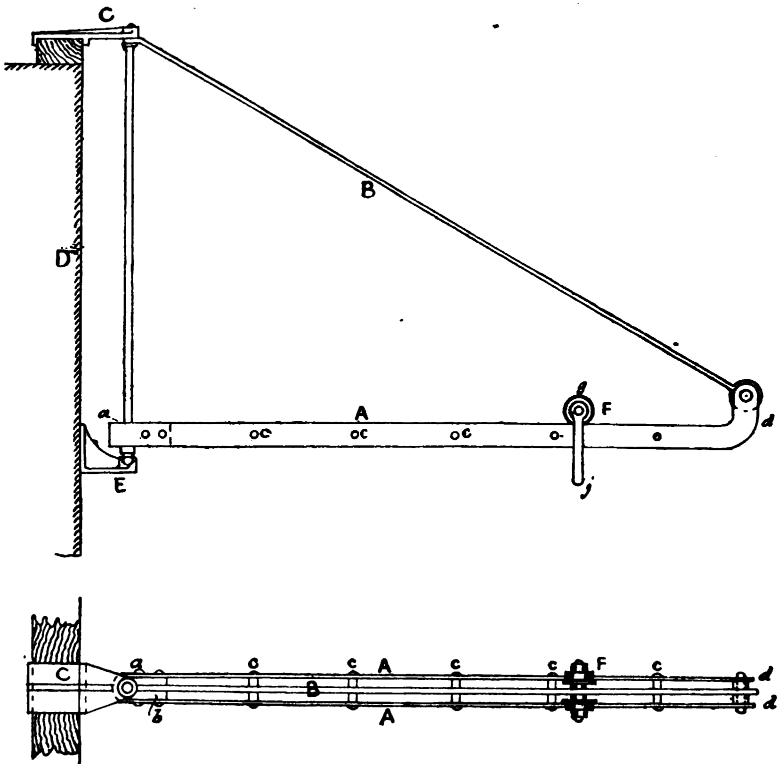


FIG. 130
Wall Crane.

pop that also. When the working line has been obliterated by machining, the other, or *witness* line, is proof whether the machining has been done accurately or not.

Lifting tackle.—No marking-off table, except the very

smallest, is complete without a jib, or wall crane, from which to suspend pulley blocks for lifting heavy work. Many castings and forgings are too lumpy to be lifted and turned about by hand. But a simple pair of differential blocks is all that is required for any work likely to be put upon an ordinary table. Such a jib is shown in Fig. 130. The blocks are hooked on to the jinny that runs along the horizontal bars, and this, with the swing of the jib, allows the pulley blocks to cover the whole area of the table.

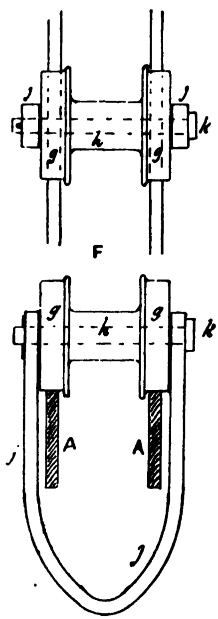


FIG. 131
Jinny of Wall Crane.

The crane is of the simplest possible construction. A bar of wrought iron, A, is bent round at the end *a*, and maintained parallel by means of a cast-iron block, *b*, and distance pieces *c*. The ends *d* are turned up to take the pin of the tie rod B, the other end of which is pivoted upon a cast-iron bracket, C, bolted to a piece of timber laid along the shop wall D. The crane is supported, and further pivots upon a pin fitting into a footstep casting, E, bolted to the wall. The jinny F, enlarged in Fig. 131, consists in very light cranes of this type, of two cast-iron wheels, *g g*, about 6 in. in diameter, cast together with a middle boss, *h*. They run upon the edges of the jib A. Sometimes angle irons are riveted on the outside of the jib sides, but only in heavy cranes. The eye *j* to which the pulley blocks are hooked is bent round, bossed up, and secured to the jinny

wheels with a central pin, *k*, upon which the wheels *g g* freely revolve. The jinny is moved along, and the jib is swung round merely by pulling at the chains of the pulley blocks.

Examples of work.—In selecting suitable examples of lining out, jobs are so numerous and varied that it is impossible to comprise all that may be said on the subject in a few pages. Typical illustrations must be selected.

Cheek.—Fig. 132 is a comparatively simple example, typical of a large number of cases that occur. The type is that of the side frame, cheek, or standard, with bearings for shafts. Both right- and left-hand cheeks are nearly, though not quite, identical in form. A is the bearing for a first-motion pinion shaft; B is that for a shaft which carries a hoisting barrel and its spur wheel. Each of these bearings is fitted with brasses and cap. C C and D are bosses for bolting down the cheeks to a truck. E is a brake strap lug. In the boss F a bell-crank lever is pivoted for tightening or letting loose the brake, the bell-crank lever being operated with a pedal or foot lever. The boss G carries a pin, upon which a lever attachment is pivoted. H H are the planing strips on the foot. These are the cardinal parts that have to be lined out accurately. The most important centres are A and B for the shafts of the gear wheels. These centres must be exact, and both frames must be precisely alike, not only as regards centres, but in respect of perpendicular heights and horizontal distances.

Frames of this general type are marked off differently, according to their size. When small, they are stood upright upon the lining-off table, and marked with the square and scriber from the table's face. When large, they are not stood upon the table, but are laid upon

PLATE 3.—Shop of C. Redman and Sons, Halifax. [*Facing p. 144.*

trestles, and struck out with straight-edges, square, and trammels. Again, the facings *a a* for the brasses, and the

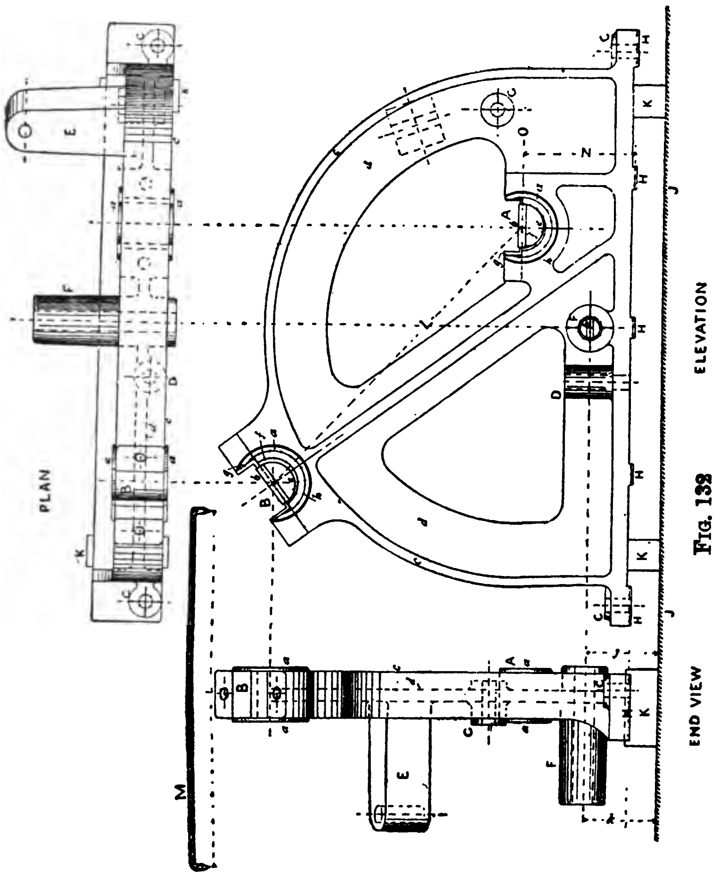


FIG. 132
Cheek Lined Out.

faces of the bosses, F G, are often planed off on a machine before any centres are lined out. As often, however, the lining off is performed before the facings are machined,

the latter being done immediately after the boring with a broad facing cutter. The choice depends on the practice of the shop, or it is often regulated by what machines, planing, milling, or boring, happen to be least pressed with work at the time. Whether the facings are left rough or machined first of all, makes no difference, however, in the method of lining out.

The first step is to bridge all the rough-cored holes either with strips of hard wood or of iron bar, *b*, driven in firmly, and to chalk the faces of the bridge pieces, and of the planing strips H.

Bearing in mind that both frames are lined out simultaneously, if they are marked while lying flat upon trestles they will be merely laid side by side upon the trestles. If, however, they are marked while standing upright upon the table, then they should be stood with the bottom flanges at the same height, and both frames exactly perpendicular. As the latter plan will afford the better opportunity to illustrate some of the cardinal methods of lining out, that is illustrated. Only one frame is shown in the figure; but it must be understood that the fellow one is standing alongside of it, either back to back, or end to end, dependent on circumstances.

The frames may be stood by the planing strips H of the bottom flange upon the table J. But it is, on the whole, more convenient to insert packing blocks, K, of, say, 1½ in. or 2 in. in thickness underneath, because then the scriber point can operate better on the facings, and dimensions can be trammelled up better from these facings than if the strips rested directly upon the table.

The frames will have to be packed up perpendicularly, trial being made with the blade of a long square whose stock rests upon the table. The blade may be tried

against the edges of the flanges *c c*, or measurement can be taken from the blade to the plated portion *d* of the frame. As the under face of the flange is rough and uneven, it will probably be necessary to insert thin iron or wooden wedges between the packing pieces K and the casting, in order to throw it into a quite perpendicular position, and to keep it steady in that position. If wedges are too thick, small cuttings of thin sheet zinc, tin, brass, or paper are inserted where required. It is as well to set the frames with their faces, or the edge of the bottom flange or foot, just over one of the longitudinal lines scribed upon the face of the marking-off table.

The frames being set perpendicularly and steadily, the next thing to be done is to mark faintly the centres of the *cored* holes for the bearings A and B; faintly, because it is very unlikely that these will be quite identical with the centres of the wheels. Next set a trammel to the wheel centres L, which should be taken, not from the drawing, but from the wheels themselves, when their teeth are put into the right depth for gearing. Also, it is the practice in most cases to make use of *fixed* trammels for such centres, in preference to the regular trammels with movable heads. There is the risk of the movable heads becoming slack, and shifting on the rod; and, further, they are not a permanent record of work done. A trammel is therefore usually made of round rod, M in the figure, and kept in the shop with the templets. This is now tried upon the centres of the cored holes A and B, and as its centres probably do not correspond with those, the question of how to average these centres has to be considered.

The centres of the cored holes may be nearer or farther apart than the wheel centres, and then the usual plan is to divide the difference equally between the two bearings.

Sometimes, however, the cored holes may happen to be so much out of truth that they cannot be made to machine up upon one side, and the holes may have to be bored larger than was originally intended, and new brasses may have to be made correspondingly larger upon the outside. But this, of course, is excessive inaccuracy. It is, however, good practice to leave more than the average machining allowance in the bottoms *e e* of the cored holes, say $\frac{3}{16}$ in., or even $\frac{1}{4}$ in., instead of $\frac{1}{8}$ in.

There is also another matter that often has to be considered. In many cases—this among others—the position of one centre is fixed in relation to some other portion of the general mechanism. The position of the bearing A is fixed absolutely, both in the vertical height N and horizontal plane, O. Hence all the adjustment that may be required will be made upon the bearing B, whose position in relation to the general mechanism may be varied a little.

Before, however, finally fixing the centres of the shafts, it is necessary to settle the accuracy of the height N from the centre of A to the foot of the frame; and the allowance for machining on the planing strips H may be made a means, as it often is, of raising or lowering the centre of the shaft A in relation to its cored hole, in order to average its position with that of the shaft B. In the other, or horizontal direction O, the centre may be moved a little if required, because although the centre of A must correspond with that of the engine crank, the whole frame can be moved $\frac{1}{16}$ in., or even $\frac{1}{8}$ in., upon its base, and bolted down to suit the position of the crank shaft, without affecting any important dimension.

Having the positions of the centres and the base of the foot finally settled, the marking off will be done straight

off. The edges of the planing strips will be scribed off on both sides of the frame, and on both frames, and also the centres of the shafts. The circles *f*, for the bored seatings for the brasses, and the lines *g* of the planed sides, for the caps to fit within, will also be scribed on both frames. It is not necessary to mark them on both sides of the frame, because when set upon the boring or planing machine, the automatic arrangements guarantee the parallelism of the work. Only in the rare exception of hand work done with chisel and file, which would only happen in the case of stoppage of machinery, is it necessary to mark work of this class on both sides of shallow frames. The case is, however, different with very deep bearings, long bosses, long facings, and so forth.

Upon each of the facings *a a*, and from the same centres from which the seating circles *f f* are struck, other circles, *h h*, of any radius will be struck. These are *witness* lines, which, remaining after the boring has been done, testify to its accuracy or otherwise.

In the figure the seating lines *f f* are intentionally shown out of centre with the rough cored holes *e e*. Occasionally they come almost concentric; but in large frames, and especially where the centres of three or four mutual gears are concerned, the want of coincidence shown in the figure is by no means exaggerated.

The long boss F may now be marked off. Being long, it will be marked on both sides. Its centre is not important, so that the centre of the boss on the casting will be the centre for boring. If those portions of the boss which are on the opposite sides of the frame are not in line, then the centre for boring will have to be averaged between the two. The height of the centre will be measured up from the planing strips on the shallow side *j*,

and the scriber being set to that, will mark off both sides *j* and *k* in turn. The centre for the horizontal, or plan dimension, will be carried over at right angles to the frame by means of one of the transverse lines scribed upon the table's face. Since we set the edge of the bottom flange upon one of the longitudinal lines scribed upon the table, if we now make the boss centre parallel with one of the transverse lines scribed upon the table, it must be at exact right angles with the foot. Measurement will be taken with a square placed upon the line nearest it. Horizontal measurement will be taken from the edge of the square to the faces of the boss.

The hole in the boss G, supposed to be drilled in the solid, will be marked on one side only, and will be placed in the centre of the cast boss. The holes in the bosses, C C and D, for the hold-down bolts, also drilled, too, in the solid, are marked in the centres of their bosses, because they are quite independent of anything else. After they have been drilled, the corresponding holes are marked from them upon the base plate. The hole, also, in the lug, E, is marked in the centre of the semi-circular end.

Observe that all the lines for machining are *centre popped*, to prevent loss of guidance in the event of the scribed lines becoming partially or wholly obscured with dirt or grease.

Cylinder.—An engine cylinder presents less difficulty than many other pieces of mechanism that might be named. Some machine frames, for example, are more difficult. The example shown Fig. 133 is the low-pressure cylinder for a compound horizontal engine.

In this Fig. A A are flanges by which this cylinder is bolted to the high-pressure one. B is a foot for bolting to the bed plate, which in this example is built up of

plate and angle. There is a corresponding foot on the high-pressure cylinder. C is the steam inlet from the high-pressure cylinder, D is the exhaust pipe, E is the steam chest, F its flange, G indicator bosses, H pet cock bosses, J facing for front valve-rod guide, K facing for hinder ditto.

In a cylinder of this type these matters have to be looked to: That the faces A and F are parallel, and at correct distances from the bore, that the flanges A and F are at right angles with the faces L L, and the centre M of the ports midway between the faces of the flanges L L, that the widths of the ports and of their separating bars are correct to width, and at exact right angles with the cylinder bore, and that the bore is in winding with the guide strips *a a* for the valve.

In this, as in other examples, it must be remembered that if I describe one method of lining out, a different mode, or modes, of procedure would be adopted by different men. It is the general or broad outlines only of these methods that need be insisted on.

We will suppose the central cored hole to have been bridged, N, at both ends, with wood or iron, and all the surfaces to have been whitened. The cylinder will then be set on the lining-off table. It does not lay in actual contact with the table, but must be supported. The best way to block it up is on two pieces of wood, O O, hollowed to the radius of the body. The overhanging steam chest must be also supported upon a cubical block, P.

Now the centres of the diameter Q of the flanges and facings, the centres of A A, and of the flange F respectively will be pricked off with compass calipers or with compasses. The point of the scribing block is then set to one of the centres thus pricked off, and if, in moving the

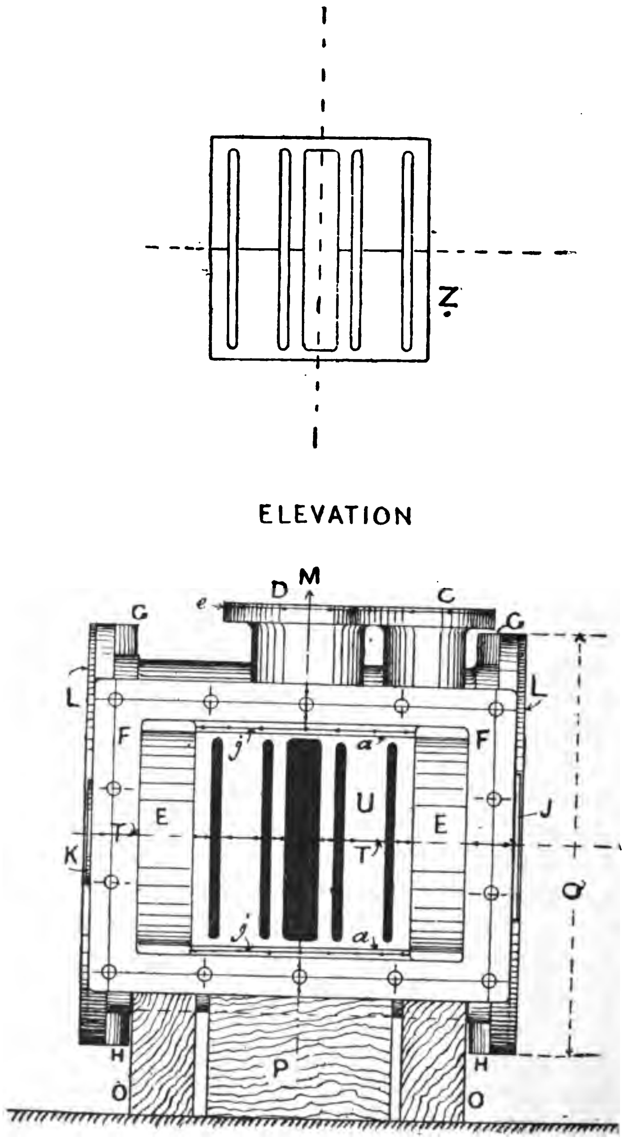
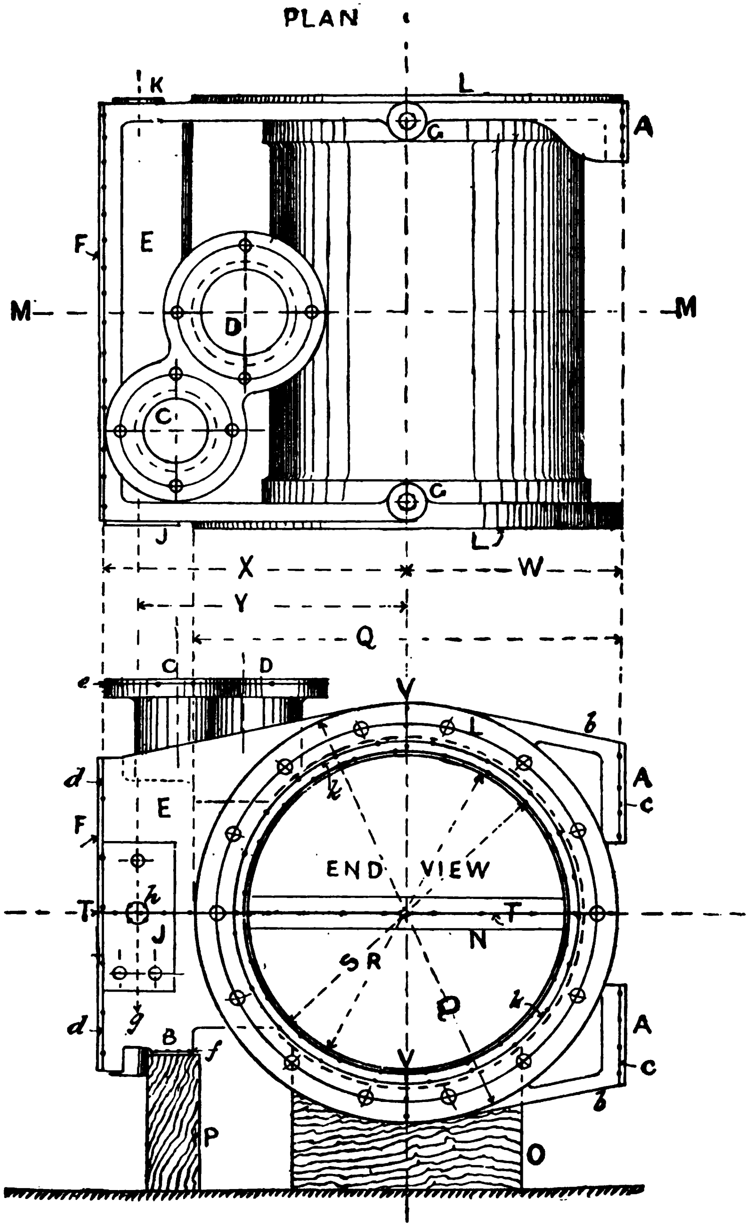


FIG. 133
Engine Cylinder Lined Out.



Plan and End View of Cylinder.

point along, and if necessary wedging the casting up more to one side than the other, each of the three centres is at the same height, then there will be no need to average the main centre line that passes through the three points. But the probability is that these separate centres will not be in line, but that the cored hole R will not be central with the faces A A and F. If the hole is out only a little, no alteration of the centre for boring S will be necessary; but if it is out much, and especially if the hole is not circular, or if the allowance for boring is very scant, then it will be necessary to move the centre for the bore upwards or downwards, of course throwing the centres of the faces A and F out also. Of the two, it is better to throw the face F out less and the face A more, because the edges *b b* can be dressed off with chisel and file, while it is very undesirable to throw the valve face out of centre at all.

It may happen that the three centres may be in line on one end of the cylinder, and not on the other. But the great point always is, in any case of this kind, to keep the centres of the outside edges of Q, and of F, as nearly in alignment as is practicable, without unduly diminishing the amounts required for machining. These amounts in work of this character are $\frac{1}{8}$ in. on all faces, so that two cuts, one rough, one finishing, can be taken off.

Now scribe the horizontal centre line T all round the cylinder, across ends L L, flange F, and body, carrying the line also across the valve face U within the steam chest.

But before this line is scribed very deeply, or centre popped, it is necessary to test the truth of the faces A A and F. For, if they are so much out of perpendicular that they will not hold up to dimensions, then it will be necessary to tilt the casting out of its proper horizontal plane,

and so throw the centre line T out of true centre with the faces A A and F, in order to make the faces stand square enough to give sufficient metal for machining to size. It is a pity to have to resort to such a measure, but cylinder moulds made, as they so largely are, with drawbacks and cores, cannot always be depended upon for accuracy within $\frac{1}{8}$ in.

But in any case, having the horizontal line T settled, the next step is to set up the vertical centre line V with a square from the marking-off table, in the centre of the circle formed by the outside of the flange Q, if possible. But it may happen that the distances W and X of the faces A and F from this centre are greater or less than they should be. Then the centre V may have to be moved slightly in one direction or the other, only, however, within the limits of allowance for machining. Both ends of the cylinder will be tried in similar fashion, and when the positions of the centre lines and faces are fixed, the verticals *c* and *d* for machining are scribed up from the edge of a square.

Immediately following, the line *e*, representing the planed faces of the flanges of C and D, and the line *f* on the ends of the flange B, will be scribed.

The centre *g* of the valve rod will now be raised at the distance Y from the cylinder centre, and the holes *h* struck on each end.

There is one other matter before the cylinder is moved, and that is the lining off of the edges of *a*, against which the valve slides. We have the centre line T already scribed. It is only necessary now to mark off a line corresponding with that centre line upon a block like that shown in Fig. 129, p. 140, and also two other lines, corresponding with the planed distances *j j* of the guide strips

a a, and transfer these last two lines from the block to the strips in the manner before described on p. 140.

And now the cylinder casting can be removed from its packing for centre popping and machining. A witness line will be struck at *k*, about $\frac{1}{8}$ in. or $\frac{1}{4}$ in. outside the line for boring, and all the scribed lines will be marked with centre pops at intervals of about $\frac{3}{4}$ in.

The lining out of the valve face U, excepting that of the guiding strips *a a*, is, of course, not done until the face has been planed over, and that face is not planed until after the face F of the steam chest has been planed. Then the valve face is planed parallel with it, and the guiding strips *a a* are planed. A templet, Z, is then cut out to fit within the strips, and to lie upon the planed face. Slots are cut in the templet of the same size as the ports, and the widths between the slots correspond with the widths of the port bars. This is laid upon the planed face, and the lines scribed through the slots represent the edges to which the ports have to be milled, or chipped and filed. Sometimes, where only one casting has to be marked out, a templet is not made, but the lines representing the port edges are set out with dividers, and scribed with a square from the planed guide strips *a a*.

When, as frequently happens, the ports and port bars do not come out to very accurate dimensions, the differences must be averaged, and less or more be taken off some of the edges. Once upon a while the valve edges may have to be slightly altered to adapt them to altered dimensions. But the allowance given for machining is usually quite sufficient to allow enough margin for moulders' inaccuracy.

The ends L L of the cylinder flanges are not usually lined off all round. It is sufficient, after testing their vertical truth or inaccuracy, to mark the length over the

finished flanges in one spot. When the cylinder has been bored, the flanges are faced at the same setting; usually with a star-feed arrangement upon the boring bar. Since the cylinder is not moved, the facing of the flanges is bound to be at precise right angles with the bore; hence the reason why lining out is not necessary here.

After all the flanges have been faced, the centre lines for the stud holes are struck round on flanges L L and F, and the centres of the holes divided out, their diameters struck, and centre popped ready for drilling.

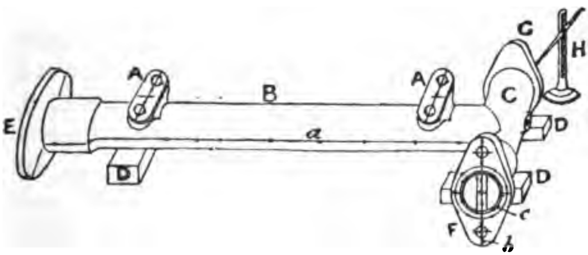


FIG. 134
Force Pump Lined Out.

Other matters—as the lining out of the tapping holes for the pet cocks and for the indicator plugs—call for no comment; because they offer no difficulty after the main lining out has been mastered.

Force pump.—Fig 134 shows a common force pump, packed up on blocks for lining out in one of its planes. The first matter is to get the feet A A, and the centre line *a* of the bores of the barrel B, and of the valve chamber C, in planes parallel with the face of the marking-off table. Ordinary cubical packing blocks D, and thickness liners are used. As in other examples, in order to get the faces of the feet A to plane up parallel with the bores, mutual

adjustments may have to be made. The feet may not only not be parallel, but they may be winding with each other, so that more metal may have to be taken off one end than the other. When adjusted, the centre line *a* will be scribed all round B, C, E, F, G with the scriber H, vertical lines *b*, squared up on each flange face, and circles *c*, for the bores struck, and witness lines around them, and the stud holes also marked.

The pump may now be bored, or the remainder of the lining out may be done first. If bored now, the flanges E F G will be also faced at the time of boring, and the dimensions over their faces need not be lined out beyond a centre-punch mark upon one side of each flange to guide the turner. If the valve seatings are merely drilled, and there is no appliance available for facing at the same time, or if the flanges have to be planed, then they will be lined out either before or after boring. In such cases the pump will be turned a quarter way round, and reset and packed up, so that the valve chamber end C stands vertically upon the table. Then the flanges F and G will be scribed round with lines representing their faced over-all distances.

The centre lines, both vertical, *b*, and horizontal, *a*, are scribed upon the feet while in the position shown in Fig. 134, and the centres of the holes through which the stud or bolts pass are marked at the same setting. The centres of the bolt holes in A A are marked after the pump has been turned a quarter round and the barrel B packed up parallel with the table. The feet may or may not be planed first. If not planed before marking out the holes, then they must be drilled before planing.

Slide valve.—Fig. 135, a slide valve, is an example of work where all faces stand at right angles with one

another, and it is in consequence marked out easily. In the first instance, the valve is laid upon the face of the

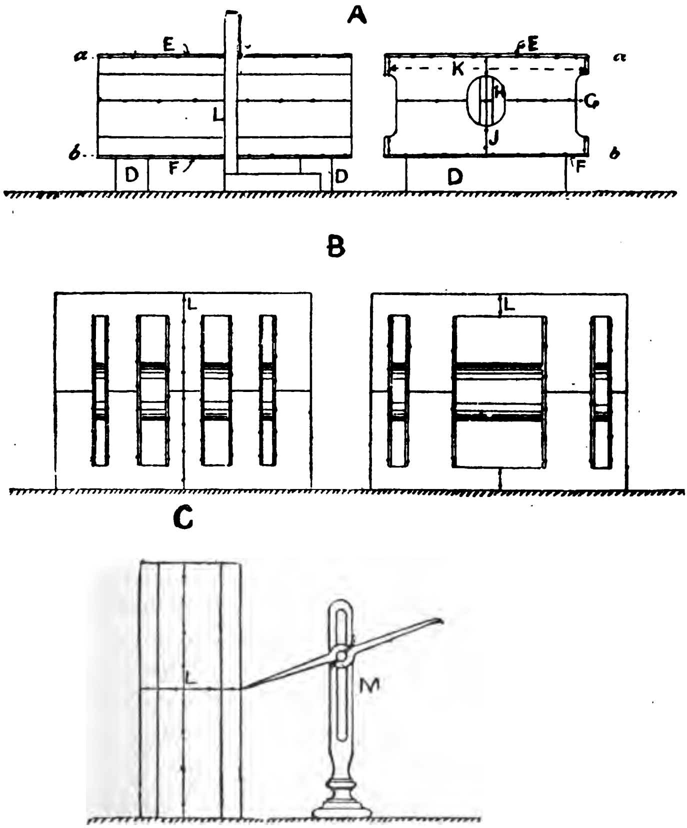


FIG. 135
Slide Valve Lined Out.

table in the position A. Such adjustment on the blocks D D with wedges or sheet metal as may be necessary to average about equal amounts for the machining off the

faces E and F must be made. I say about, because the faces have to stand at certain distances from the centre G of the hole H for the valve rod, which hole is not always cored exactly true, and, in consequence, a little more may have to be planed off one face than the other, in order to correct the inaccuracy of the cored hole. The planing lines *a b* are then scribed round the edges of the valve. Next, the vertical centre line J, central with the cored hole H, is scribed up on each end with a square from the face of the table. From these lines, the width, K, of the valve is marked with compasses upon each end, and scribed up. At the same setting, the vertical centre of the valve, lengthwise, will be marked up, as at L. This, however, may have to be corrected subsequently with the centres of the ports. The casting is then removed, and centre popped, and planed on the lined-out faces and edges, and brought back to the table to have the port edges marked, which is done as follows—

The first thing is to get a centre line round the planed faces and edges of the casting. Its position should be averaged from the cored ports on each face, so that their edges shall all hold up to width, and their bars also be of the right width. There are two ways in which this line and the port edges can be marked: either when the valve is laid upon the planed edges of the strips, as at B, or when stood upon end, as at C. If stood on its edges, as at B, then it will be turned over from edge to face, in order to carry the centre line round on all four faces. If stood as at C, the centre line can be carried round all four faces with the scribing block M, without altering the position of the casting upon the table. If the ends of the casting are planed, even with only a rough cut, then

it will stand perpendicularly without any packing up. It does not matter which plan is followed.

If the casting is stood upon end, then the port openings will be marked off in horizontal parallel lines with the surface gauge. The distances of their edges from the centre line L will be given either by pricking off with compasses direct, or by transference from another vertical face, according to the method already described on page 140. If the casting is stood upon edge, as at B,

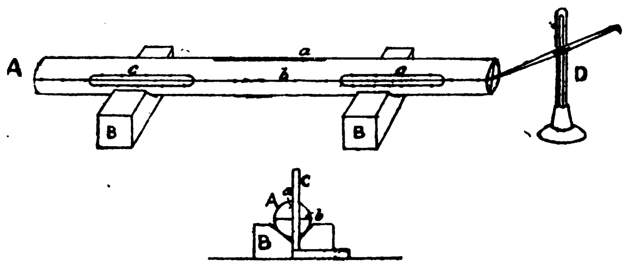


FIG. 136
Lining a Shaft.

then the port edges will all be marked from the square set upon the face of the table.

Shafts.—Take, now, a piece of work that has no square face to stand upon—the shaft A in Fig. 136. Upon this shaft it is desired to mark key-ways at right or any other angles with each other. For this, the vee blocks B B are used. Or, in some cases, planer centres may be substituted, when the chucking centres of the shaft are left in. The shaft being already turned, and supported upon the vee blocks, the required lines, whether at right or at other angles, are set out upon one end. Say the lines are to be at right angles: then a vertical, *a*, is scribed up through the centre with a square, C, and a horizontal, *b*, also

through the centre, with a scribing block, D. The horizontal is carried round on the side, or sides, of the shaft where the key-way has to be slotted. The width of the key-way, or key-ways, *c*, is then pricked off with dividers, and its edges scribed at the same time. Or a slotted templet is employed for the purpose.

The shaft is next rotated upon the vee blocks, and reset, with the horizontal line *b* brought into a vertical position, thus bringing the centre line of the key-way, *d*, that was above or below before, to the side, where it is also scribed with horizontal lines.

If the key-ways have to stand at any other angles than right angles, then the angles are first set off upon the ends, and the shaft rotated until their centre lines are successively brought into a horizontal position—that is, in the same horizontal plane with the centre of the shaft.

In standard work of this character special templets are used for lining out the key-ways. These are described in the chapter devoted to templets and jigs (p. 106).

The planer centres are used for lining off work of this character when no necessity exists for setting off lines from the ends of the shafts. In some cases there is an advantage in using them. When the chucking centres remain in the ends of turned work, they afford a quick and ready method of supporting that work, and it can be turned quickly into any new position required for marking the positions of key-ways, grooves and flutes.

Shaft centres.—To obtain the centres of shafts and of circular work generally, various devices are resorted to. For work of small diameters, the compass caliper is commonly employed, in the method shown in Fig. 137. The caliper leg A is held outside of the shaft, and a short

line is scribed with the compass leg B upon the end of the shaft. This operation is repeated four or six times at roughly equidistant positions, and the mean of the lines scribed upon the ends is the shaft centre.

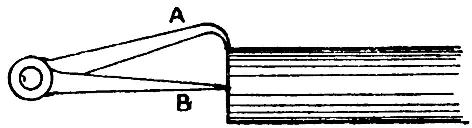


FIG. 137
Obtaining Centres with the Compass Caliper.

Another way is to set the shaft in vee blocks, set the scriber point of the block approximately to the centre, and rotating the shaft at intervals through distances equal to about a fourth or a sixth of a circle, scribe short

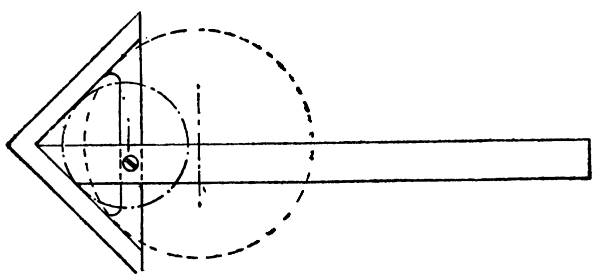


FIG. 138
Centre Square.

lines on the ends, the mean of which will be the shaft centre.

Other methods are by means of a centre square, or of a bell-centre punch; the latter being adapted for shafts, the former chiefly for discs. The centre square, Fig. 138, comprises a triangular head, to which is screwed a flat rule with one edge in line with the apex of the triangle

so that any round objects placed against the two upstanding inner edges of the triangular piece may be centred by turning the tool into three or more different positions, and striking lines which must cross at the centre. The centres of discs, however, are often found by means of compasses, thus (Fig. 139): several centre-pop

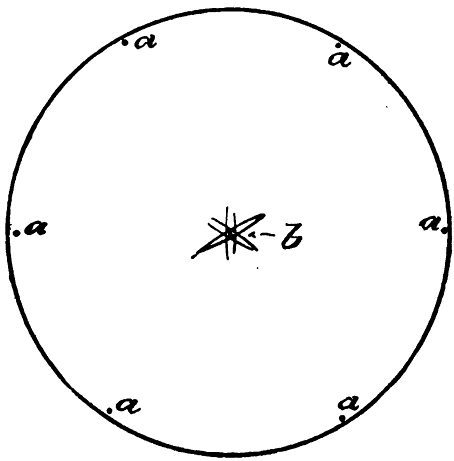


FIG. 139
Obtaining Centre of Disc with Compasses.

marks, *a*, are made just inside the edges of the disc. These form centres for one compass leg, from which the other leg scribes a short radius. The intersections of these radii at *b*, or their mean when they do not quite intersect, is the centre of the disc.

But when the disc has sufficient thickness to stand on edge, the scriber point is often used in preference (Fig. 140). The disc may be steadied, if necessary, with wedges, or by the hand, while the successive scriber marks are being made, whose intersection gives the centre.

To get a centre line across a cylinder or pump cover, where a straight-edge cannot be employed, because a stuffing-box or similar projection stands out in the way, the surface gauge is used, Fig. 141. The cover being set quite vertically upon the table, the line *a* carried across the face of the cover will exactly bisect the circle *b* of the bolt centres; and from the intersections *c c* so obtained, the whole of the bolt centres can be divided round.

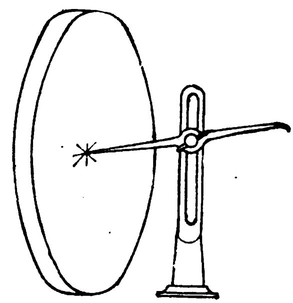


FIG. 140
Obtaining Centre of Disc with Scribing Block.

Levers.—Levers and rods of various types form a large section of lined-out work. There is scarcely a mechanism of any kind without its numerous levers and rods. They are seldom mere flat rods, but are usually bossed up with bosses of various diameters and thicknesses. Such levers are generally lined out on one face only—that is, directly on one of the boss faces A in Fig. 142. Whether they are marked out also upon the sides B usually depends on what arrangements exist for machining.

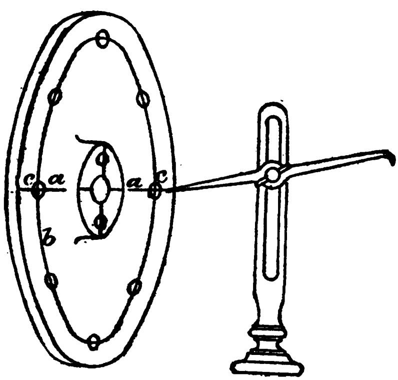


FIG. 141
Obtaining Centre Line of Cylinder Cover with Scribing Block.

Taking first a lever like Fig. 142, the methods of lining out will differ according to whether the lever has to be shaped by hand with chisel and file chiefly, or whether it has to be shaped in lathe and shaping machine. In the first case it will have to be marked out on all four faces; in the latter it need, as a rule, be lined out only on one. In the first case, chisel and file being used, lines for their guidance must be marked upon each edge, for if marked upon one edge only, constant testing with the square from

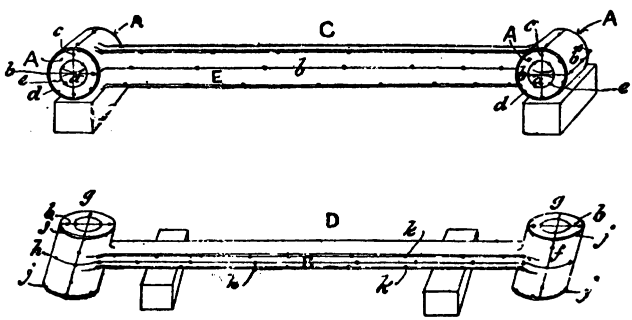


Fig. 142
Lining Out a Lever.

the surface of the lining-off table, or surface plate, or lathe bed would be necessary to insure that the faces shall be at right angles with each other and the thicknesses parallel. But if machined, it is sufficient to line out on one face only, the shaping or milling machine insuring parallelism of parts.

We may illustrate the maximum amount of lining out that would be done on the supposition that all shaping has to be performed without the aid of a machine, using as an illustration the lever in Fig. 142.

The first thing to be done is to block it up upon its

side, as in Fig. 142, C. Check the opposite flat faces A A with a square from the face of the table, in order to average such deviation from parallelism as may exist on those faces. Roughly indicate the centres of the bosses by means of dividers set just within the edges, thence striking short radii at *a*, the bisection of which will be very approximately the centres of the bosses, through which the horizontal line *b* will be scribed on both faces: either end of the rough forging of the lever being packed up if necessary to bring the centres parallel with the face of the table.

The longitudinal centres *c c* will be next trammelled off directly, and squared up from the table, if the bosses are in the same plane. But when the face of one boss stands out beyond the face of the other, the dimension will be set out upon the table beneath the bosses—starting from one of the lines on the face of the table, and squared up from those set-out lines. The boss circles *d*, and the circles *e*, for the drilled holes will then be struck. If, as we suppose, allowance for machining has been left upon the webbed portion E of the lever, then lines will be scribed along that, as shown, equidistant from the centre line *b* already marked.

We can mark out the opposite face of the forging without removing it from its present position, or we can mark it by giving it a quarter turn, so bringing it into right angles within the position shown in Fig. 142, C. If we let it remain in its present position, then the centres on the farther face will be marked by carrying lines corresponding with them across the table immediately underneath, and squaring up from them upon the farther face. Without actually marking lines on the table, a square might be carried across, in a position parallel with the

centre lines of each boss, provided, of course, that the lever stands parallel with the edge of the table against which the stock of the square is laid. From the edge of the square so set, measurement will be taken to another square, and a line, *c*, carried up from that second square over the boss faces. The boss centres will be scribed from the intersection of this line with *b*.

But if the lever is to be turned quarter way round, which would be advantageous in the case of levers with several bosses, having faces standing at different heights, then the central line *b* must be carried round the ends b^1, and when the lever is turned round, as in Fig. 142, D, it will be reset by means of these end lines b^1 brought into a vertical direction, and tested with a square from the face of the table. It will be set not only thus, but also adjusted for height, until a centre line carried along horizontally with the scribing block will allow sufficient metal on all faces for finishing to dimensions. Then the vertical lines *f*, carried up the boss sides, will be the centres of the bosses, at exact right angles with the line *b*, and these will be united by lines *g*, drawn across the boss faces. The intersections of these with the horizontal line *b*, previously scribed, will give the centres whence the boss centres will be struck.

Of course, the shaping of the bosses and web will obliterate the centre line *f* last marked, which is only obtained in order to get the square lines for the boss. When the bosses and web are finished, then the lever will be again set, as in Fig. 142, D, the centre line *h* put on, and the positions of the boss faces *j* obtained and scribed round, and also the lines *k* corresponding with the faces of the web. Fig. 142, D, shows the lever thus marked out.

In workshops which are provided with shaping machines the lever would be marked out only upon the face A, and not squared over to the opposite face at all. The bosses would be formed upon a shaping machine by means of the circular-shaping attachment, and the web, if machined at all, would be shaped by a succession of short cuts taken transversely on a shaper. Only, however, in the case of exceptional classes of work is it the practice to shape these webs on a machine. Generally they are simply ground on emery wheels, and polished afterwards on buffs.

The best method of finishing bosses of this kind is by turning them in a special gap lathe, as far as the faces of the web, and then shaping the narrow width corresponding with the thickness of the web in a shaping machine. Or they can be turned in an ordinary lathe by making the cutting tool revolve and feeding the boss forward on the slide rest. Or they may be shaped right across through half their circumference, and the rest be done with the file. Or they may be wholly shaped with the chisel and file. Or they may be milled.

After the bosses have been shaped, they are bolted with one side against an angle plate, upon which the bosses are faced, with or without lining out for the purpose. It is only necessary to have their exact distances from the centre of the web; the angle plate and the machine ensure their standing at right angles with the sides. But if bossed up in the lathe, they will be also faced at the same time.

I have described this job at rather more length than its simplicity might seem to merit; but it is a typical case, equally adapted to work shaped entirely by hand or by machine. But in work of this kind done in a shop

well equipped with machines, there is relatively little lining out done. Levers are commonly marked out only upon the bosses, leaving the webs unlined, these being forged or stamped so accurately that they only need be ground a little, and merged neatly into the radii dying down from the bosses. Quite commonly, also, they are not blocked up on the lining-off table, but laid down any-

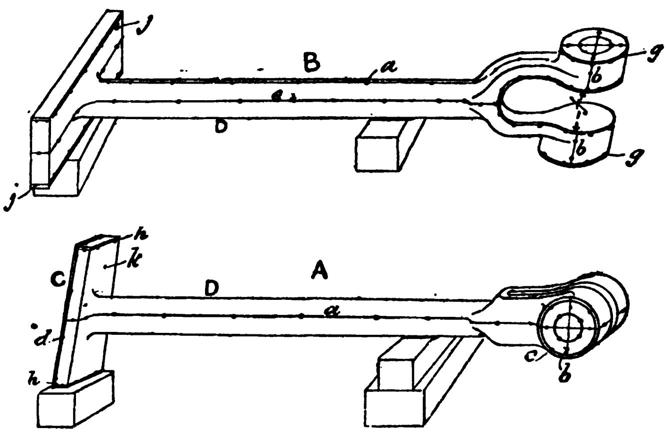


FIG. 143
Lining Out a Connecting Rod.

where and marked. The centre line *b* is scribed through the bosses, and the transverse centres *c c* marked with compasses or trammels. If the bosses stand at different heights, compasses or trammels having one leg adjustable for height are used.

The connecting rod in Fig. 143 cannot be lined out without taking two settings at right angles with each other. It will first be marked in the position A to get the centre line *a*, the centre *b*, and the circle *c* of the boss and its holes. At the same setting the length over the

flat end C will be determined, and the line *d* marked up from the table. The opposite or farther face of the lever may be similarly marked by means of lines squared across and up from the table, or by turning the rod a quarter round, and setting the horizontal centres in Fig. 143, A, vertical, as in Fig. 143, B, according to the method described in connection with Fig. 142. The boss curves *c* will now be machined, and the end C and edges *h* may be faced. The rod will then be returned to the table, the centre lines *b* carried across the shaped ends, and set vertically with the square in the position in Fig. 143 B. The other longitudinal centre line *e* will then be obtained and carried round, the width of the gap *f* marked, and also the lines *g* showing the width over the bosses, and the lines *j* and *j* on the flat end C, to which lines those parts will be subsequently machined.

The intersections of the centre lines *a* and *e* upon the ends will be the chucking centres for turning the body of the rod. Frequently, however, this portion is turned before any shaping is done, care being taken, by a rough preliminary test, to average the centres of the body or shank with the two ends, so that these will afterwards hold up to size. At the same time that the rod is turned, the end C is also usually faced in the lathe, and the edges *h* are usually turned to a radii equal to their own distance from the centre. The inner face *k* is also commonly turned at the same time. This is better than planing the faces *d* and edges *h*, as previously mentioned. The chucking centres remaining upon the ends when the work is done in this fashion, are guides to the marker-off for obtaining vertical and horizontal centres on the table.

If the gap is roughly cut out in the forging, the chucking can be done at that end by fitting a shouldered

bridge piece across, or by holding that end in a dog chuck, or on an angle plate.

If the gap is narrow, the forging is frequently left solid, and slotted out, as is the case in Fig. 144 which shows the forked end of an eccentric rod marked for slotting.

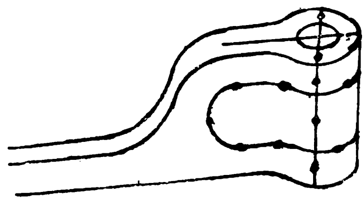


FIG. 144
Forked End Lined Out.

There is a large class of levers, the bosses of which stand out from their webs to such a considerable distance that they are therefore almost necessarily turned or "bossed up" in the lathe. In cases of this kind, it is customary only to line them out on one face, Fig. 145. Each boss, if

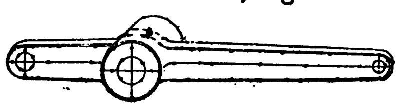


FIG. 145
Lever Lined Out.

there are two or more on a lever, is turned in succession. When any single boss has been turned, it is also faced and bored at the same chucking. The face and the hole are therefore bound to be at right angles with each other. Afterwards each boss is chucked, either by its outside edge, or by its hole, and the face and outside edge on the opposite side of the web are turned. These are, therefore, bound to be parallel and concentric respectively, with the portion of the boss upon the opposite side of the web.

These portions of the bosses that cannot be turned, namely, the portion *a*, equal to the thickness of the web, are shaped in a shaping machine or milled.

In these cases, again, it is not common to mark the webs out. They are shaped or ground or milled from boss to boss on flat faces and narrow edges, after the bosses have been finished to size.

The subject of lined-out work is interesting and instructive, and the methods that may be adopted very varied. But enough has been said to illustrate the main principles by which the marker-out is guided.

The methods of fixing and machining these examples of lined-out work do not concern the fitter, being done by quite a distinct class of men. Only in some cases, as in outdoor repair jobs, in very small shops unprovided with suitable machines, are faces chipped and filed, and portions shaped by hand work. Only so far, therefore, as may seem desirable from the standpoint of the workmen unprovided with mechanism, shall we regard the hand processes involved in the shaping of outlines.

Shop drawings.—A good drawing, even though intricate, is seldom difficult to read, but imperfect ones give much trouble. Good, here, is used in the sense of completeness in regard to details. It is in the want of this that many drawings fail and give trouble to those who have to work from them. This does not matter so much when the work represented is of a well-known class that is being regularly done. But with untried work it is tricky and troublesome.

The way to read a drawing of a piece of mechanism is to begin with the broad outlines, before troubling about details. Compare the elevations and plans, noting the corresponding outlines in each. When practicable, it is of

great assistance to have the various views in line—that is, end elevation in line with the front, and the plan or plans directly below or above these, the same centre lines running through. It is easy then to trace the similar parts, and also to scale or measure them; or if the drawing is pinned on a board, one can use a T square with advantage in comparing lines in plans and elevations.

When one has got, so to speak, the hang of the thing, then the details must be studied. Here a knowledge of the method of operation of the mechanism has to be gathered, for without this the meanings of some details will not be so clear. It is these details that occupy time, and a man cannot begin his marking off until he understands the drawing. The very minute details need not be studied so closely as the main relations of the details to each other—such as the connections of rods, levers, screws, gears, slides, and so forth.

In such matters as these, one finds great differences in drawings. The fully-detailed drawings, from which absolutely nothing, however trivial, is omitted, are so uncommon that they come as a pleasing surprise. As a rule there are few drawings in which absolutely complete details and dimensions are given. I am not speaking now of that conventional kind which are well understood in the shops, though not given in strict detail, such as dotted circles for gear wheels, parallel lines for screw threads or for springs, and so forth. The meaning of these is always well understood, and they do not cause blunders. But the details that are too often omitted are second views of a detail wanting, or imperfectly indicated and left to the imagination to fill in, or information to be sought, with loss of time. It is impossible to overload a drawing with details.

Other hindrances are caused by omitting to indicate where detailed sections are taken through, to omit to show all sectional views by suitable shading or colouring. The distinction between dotted and full lines is not always observed.

Some drawings are sadly lacking in centre lines, dimension lines, and dimensions—matters which have to be ascertained often with subsequent waste of time. Another trouble with drawings arises from the multiplicity of lines in some portions, which are very difficult to pick out and distinguish one from the other. Such portions should be indicated by distinct detailed views.

The use of scales is far less common in workshops now than formerly, because the practice of making small scaled drawings has given place to the making of full-size, or half-size ones. Many a time has the writer done his work by the use of the conventional scale—1, 1½, 2¼, 3 in. to the foot, working from drawings in which castings, forgings, and plated parts were all shown together, and picking out therefrom his own particular section in detail. The making of a scaled drawing is often accepted as absolving the draughtsmen from the necessity of inserting all dimensions, many being left to be taken by scale. It is a wasteful system, and leads to error in the hands of careless men. To-day such a system would not be tolerated in any shop run on modern lines. It is recognized now that a shop drawing should contain no small scaled parts, if they can be drawn full size, or to a large scale. The use of sun prints has multiplied the resources of the drawing office, and there is no objection on the score of expense to reproducing large prints for shop use. The time of a mere mechanical draughtsman copying, or tracing, or printing is of less value than that of skilled mechanics, to say nothing of the cost of blunders in

the shops. There is no objection, either, to having prints of large dimensions, showing in some cases a machine tool or an engine, etc., to full size, or to half or quarter size, and in the latter case many details to full size.

Another point is, that all details, without exception, should be picked out and shown separately, even to the minutest parts. Every slide, screw, spring, pin, and bolt ought to be thus shown. Some drawings of this class are models for shop use, since there is no possible chance to read them wrongly, nothing being left for the judgment or imagination of the workman to fill in. If one portion is tooled and another not, the drawing indicates this; if an edge is rounded, though but for appearance, the radius is given, and so in every one of the details of a piece the drawing is explicit and full. To line off work from such drawings is easy by comparison with the task of the marker-out, who has to fog out his details from a mass of details of other kinds, and using scales.

CHAPTER X

CHIPPING, FILING, AND DRIFTING

After work has been marked out, the question of how best to remove material and to finish surfaces may or may not be a matter of concern to the fitter. In large workshops it is a matter that does not concern him, because the lined-off work is mostly taken at once to the machine shop and turnery, and it is not brought to the fitter until the machining is all done. Exceptions there are, of course, as when cast work has to be fitted by chipping and filing to plated and wrought-iron work, and boiler work; but as far as machining is concerned, the fitter has nothing to do with the formative or shaping part of the work.

In very small shops, however, where there is a paucity of machines, the workman has to do some—often a considerable proportion—of the shaping to outline with hand-operated tools. This is an inevitable consequence either of lack of machines of types suitable for the purpose required, or very often because the machines available are limited in capacity or power. For this reason we may assume that the readers of this work include many who have to resort to makeshifts and imperfect methods of getting through their work. With these, the question often is, not how a given job would be done in a large workshop, but rather how may it be best done with such makeshift appliances as are available. The writer remembers to

have seen in his youth much work done with chisel and file, upon which chisel and file are never now used in the large shops. Thus, the valve faces of very large cylinders were chipped and filed, which are now done in the planing machine or with portable machines; surfaces were laboriously got up by draw filing and emery cloth, now done with an emery wheel; bosses and rods were chipped and filed, that are now either shaped or ground; angular brasses were fitted by filing into their plummer blocks, where turned brasses are now fitted into bored seatings; wheel teeth were chipped and filed, that are now more commonly moulded smoothly and accurately, or else cut by machine.

Work is hand-shaped to various outlines by chipping, filing, scraping, grinding, and drifting. It is not convenient to consider these as altogether distinct from one another, but rather as having a natural dependence and sequence.

Chipping.—Take a broad, plain surface, such as would be planed in a machine in half a day, but which, done by hand, would take at least three or four days. Such a surface has to be operated in detail thus: First, the edges are chamfered off with chisel and file down to a line scribed round the edges. Always, before commencing to remove a quantity of material by filing, it is well to chamfer the edges down to the line which has to be worked to. If much in amount, it will be chipped and filed; if little, filed only. The advantages are, that the amount of material that has to be removed in order to get down to the termination of the chamfer can be seen at a glance, without bending down to look at the line itself, and that there is little or no risk of unwittingly going below the line.

Next, a number of cross grooves are run across with a cross-cut chisel, about $\frac{1}{4}$ in. or $\frac{3}{8}$ in. wide, at convenient intervals—say from 1 in. to 2 in. apart—less or more, according to the extent of the area that has to be operated. The truth of these grooves is tested with a straight-edge. By this device the bulk of the surface chipping is localized, much diminishing the risk of the broad chisel cutting below the required level when operating about the central portions of the area.

A keen edge is requisite to chip a surface freely. Chip in a direction away from the edge, rather than towards it. If the chipping is being done in lines parallel with the edges of the work, hold the chisel slightly diagonally, so that the force of the blows shall be inwards rather than outwards. Neglect of this will perhaps result in some portions of the edge becoming broken out. In the central part of a piece of work, the chisel-cuts may cross and recross in all directions. Fig. 146 illustrates the way in which the chisel and hammer are used.

Filing.—Not many years since, the file was the principal hand tool in our workshops. It was employed for truing large and small surfaces, both flat and curved—work that is now done so much more rapidly with planer and shaper. Intricate forms, combinations of convex and concave curves once filed laboriously to templet, are now done more expeditiously with milling cutters. Yet the file still holds a place in shops as a corrective tool. Much work that comes into the fitter's hands from the machines has to be still further trued up and adjusted, first with file and then with scrape; for machined surfaces fitted to machined surfaces without further correction are usually too rough for the best classes of work. Apart from the more or less ridged surface of machined work, due to the feed of the tool,

there is the distortion that frequently follows from clamping it upon the machines and lathe chucks—distortion which it is the function of the file and scrape to correct. And a very large part of the difference in the cost of second-rate machine tools and those of first-class quality is due to the additional time occupied in hand work done on the latter. The finest fitting of sliding surfaces done

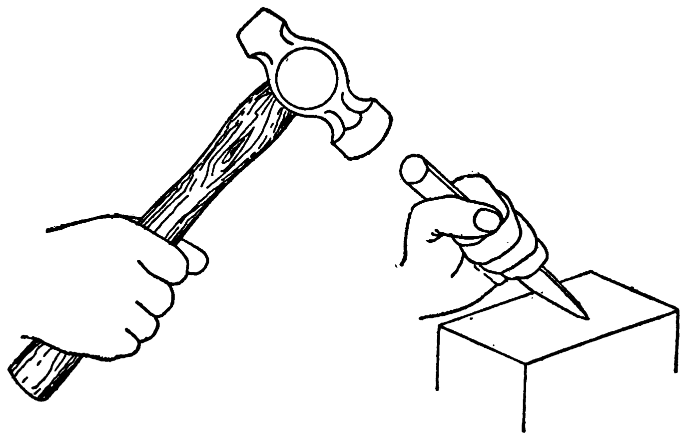


FIG. 146
Chipping.

by hand with file and scrape on the best mechanisms really begins at the stage at which those of inferior quality are sent out of the shops for delivery.

Because the file lacks the perfect guidance possessed by some classes of tools, skill in its manipulation is essential to the accuracy of work done with it. For this, considerable practice is requisite; but at last the practised hand feels intuitively how to operate the tool in various directions —now heavier, now lighter, now taking a broad surface, now localizing the efforts.

The first difficulty experienced by beginners is that of filing a *flat* surface: it will become convex. Yet files are for the most part—that is, all except those which are called "dead parallel"—convex in the longitudinal direction, and therefore ought, it might be supposed, to make the work slightly concave. The reason why the surface filed becomes rounded is that most pressure is given first by the right hand on commencing the stroke, and then by the left hand towards its termination, whereas the pressures should be as nearly as possible in equilibrium—that is, the effort should rather be to press harder with the left hand upon the point of the file at the commencement of the stroke, and harder upon the handle near its termination. In this way the file is made to *hang* well to the central portions of the work, instead of slipping over those, and pressing harder upon the margins.

There is also a difference in metals. It is easier to file wrought iron than cast, and easier to file any iron true than hard gun metal. The file *clings* to wrought iron and steel; but it slips over hard cast iron and over hard gun metal—to use an expressive term, the latter are *greasy* by comparison with the former.

This filing of surfaces level is the first, and the chief, difficulty, which has to be encountered, and which, when mastered, like the equally simple, yet equally difficult, task of planing a piece of wood true, is never forgotten.

Filing is like most other work—it cannot be done at random, or recklessly. Random work will spoil the files, make wasters of the work, and will yield inaccurate results. But the precise details of working vary, of course, with area, and with contour, with broad and narrow faces, with convex and concave surfaces. The best plan will be to consider the subject under two types: plain work of large

area, and small and delicate work in which the area is inconsiderable. We will consider the first at present, the second in the remarks to follow.

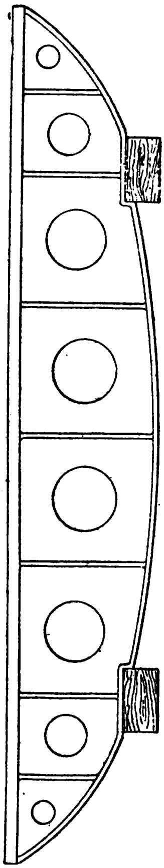


Fig. 147
Large Straight-edge.

For very heavy work, requiring the removal of a large quantity of material, a coarse, rough-cut file is used. But for by far the general run of work a bastard file is used at the commencement, and when the bulk of the material has been removed, this is followed by the second-cut, or the smooth file.

To test the accuracy of a surface that is being filed, both straight-edge and surface plate are employed; the first in the earlier stages, the second in the later ones. At the beginning it is quite sufficient to hold the straight-edge across the work, lengthwise, crosswise, and diagonally in succession, when the higher portions of the roughed-out surface will be indicated by the contact of the straight-edge therewith, without any artificial assistance derived from the transference of red lead from the straight-edge to the surface of the work.

Large cast-iron straight-edges are made, as in Fig. 147, with ribs and lightening holes. The straight-edge may stand on feet, as seen, or it may be suspended from a crane or hoist, upside down, to try upon the work.

During this preliminary roughing down the bastard files are used with the maximum of pressure, the hands

holding and operating the file as shown in Fig. 148, and nearly the entire weight of the upper portion of the body being thrown into the work. The right elbow is kept almost close to the body, and the body and left knee are moved in unison with the file. The feet are spread at about 2 ft. or 2 ft. 6 in. apart, to enable the workman to stand firmly, and put the utmost force into the strokes. The average height at which to set the work for filing is at the same level as the elbow. Heavy filing is done better with

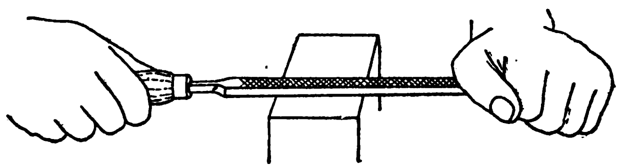


FIG. 148
Heavy Filing.

the work at a slightly lower level; for delicate filing it should stand rather higher than the elbow.

The weight of the upper portion of the body is thrown into the forward strokes of the file. But during return strokes the file is relieved altogether of that weight. It is not actually lifted from the work, but simply continues in contact with it, without pressure. If the pressure is continued the file will soon become dulled, in consequence of the fracture of the minute teeth. The magnified illustration of the teeth of a file (Fig. 149) will show how weak the teeth are relatively to force applied during the backward stroke by comparison with the forward or cutting stroke. There is plenty of metal backing the cutting edge in the thrust, there is practically none afforded

during the return by the nearly perpendicular faces of the teeth.

The file is not moved in a straight invariable direction, but both forward and diagonally, now to right, now to left —a few strokes in one line, then a few in another—obliterating the marks left by the first—a variation which partly relieves the hands, and is more expeditious than constantly working in one set of lines.

To use a roughing file continually on its broad, flat surface is not the most expeditious way of removing material in quantity, or to economize the life of the file. If a lot of roughing out has to be done, the best way is to use edges and angles, and the unworn portions of half-round files, and to use these in various diagonal directions, crossing and recrossing at almost all angles. Generally the flat files wear out quicker than the backs of the half-round ones. When a considerable amount of roughing down has to be done, therefore, it is economical to use the backs of the half-round files for the purpose. This not only saves the flat files, but the half-rounds cut more rapidly than the flat ones, so that time is economized as well as tools.

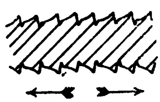


FIG. 149
Teeth of File—Enlarged.

When the roughing out has been carried so far that it becomes difficult to detect any inequality in the surface of the work by mere observation of the light between the straight-edge and the work in whatever direction the straight-edge is held, then recourse must be had to the red lead test. Red lead is made into thick paste with oil, and is smeared equally along the edge of the straight-edge. The transference of this colouring matter from the straight-edge to the surface of the work affords a delicate test of the reduction of the surface to the accurate level

required. During this process the file is used with less pressure, and its action is rather more localized, as in Fig. 150, the point of the file being held between the fingers and thumb of the left hand, instead of the ball of the hand being pressed upon it as in Fig. 148. Much of the weight of the body is still thrown upon it, but not uniformly, being graduated more, according to the quantity of material that has to be removed from a given spot. Also, a fine or smooth grade of file is generally made use

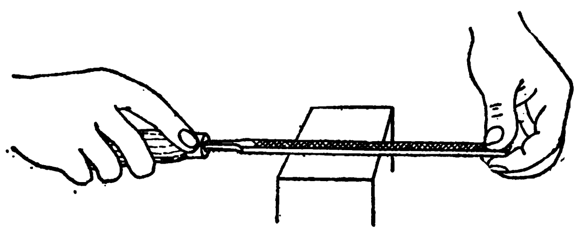


FIG. 150
Light Filing.

of, until at length the surface is wrought into a state of accuracy in which the straight-edge fails to indicate any very appreciable difference in level.

The proper method now is to have recourse to a surface plate. If the work is small, and of no great weight, its surface is turned over on that of the plate; if massive, the plate is turned upon the work. A thin film of red lead is rubbed over the surface of the plate, using the finger or a bit of waste for the purpose, and now the surface that appear so true when tested with the straight-edge merely, is seen to present very few points of contact with the plate. But a very slight amount of reduction with the file will serve to reduce these points of contact down to, or even below, the general level, so that at this later stage

the work must needs be proceeded with cautiously, and frequent recourse must be had to the test of the surface plate. The red lead must be applied more and more sparingly, for if applied thickly, it will cover nearly the whole surface of the filed work, instead of indicating the highest points merely. Also, the finest files will be brought into requisition; and frequently, instead of being operated along their whole length, an inch or two only nearest the point will be used—the fore-fingers of the left hand affording all the pressure necessary, as in Fig. 151.

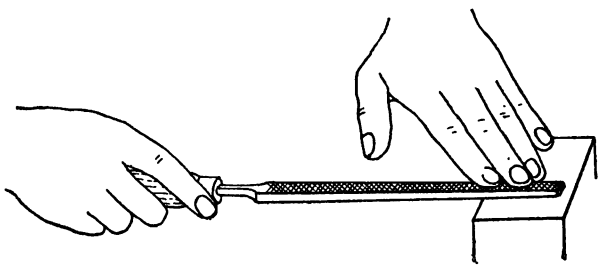


FIG. 151
Finishing.

Thus in each successive stage of filing, greater and greater localization of effort is essential, less and less material is removed, and finer files are used, until the utmost accuracy that is attainable by filing is reached. If a still greater degree of accuracy is wanted, then the scrape is employed, as in the sliding surfaces of the best work, and in the best steam joints. But for a large class of work nothing is done after the filing is completed.

There are few shops so destitute of mechanism as to necessitate filing such work as this instanced, and even in such shops it would pay better to send large work out to be machined rather than to do it by hand. But in outdoor

repairs it may sometimes happen that a valve face will have to be treated in such a way.

But the majority of work that is filed by hand is always of small area. Yet small faces that are required level must be trued up by essentially the same methods as those of large area. Only there need be little or no cross cutting; perhaps little chipping at all to be done. Yet always the same sequence of filing will have to be followed, and the same testing by straight-edge and surface plate.

Scraping.—We have considered only the truing up of single or independent surfaces, without reference to the mutual contact of opposed surfaces. Yet, neither by filing, any more than by machining, is perfect contact attainable. To obtain the best possible contact, the scrape has to be brought into requisition, and in some classes of work, emery powder or sand. The latter, however, is not employed for plain surfaces, but only for circular outlines, the emery for lapping or bobbing, and the sand for grinding in, but they have no relation to the kind of accuracy with which we are here concerned.

The operation of reducing opposed surfaces to perfect contact with the scrape is not difficult; but it calls for the exercise of much patience and caution. For it is very easy to undo the work of an hour or two by an incautious removal of too much material from one spot.

When two surfaces have to be brought into mutual contact, one of them should be brought into as perfect accuracy as it is possible to bring it, using the test of the surface plate. It will then be smeared with a very thin solution of red lead, and the opposed surface of the corresponding piece of work tried upon it, the surfaces being slightly rubbed over one another three or four times, with movements partly sliding and, if practicable, also through a

small arc of a circle. The red transference spots will then be removed with the scrape, held as in Fig. 152, the surfaces wiped clean with waste, and the work tried in contact again—and so on. As the contact of surfaces becomes more perfect, a little oil alone smeared over with the finger will suffice by its transference to indicate the higher points.

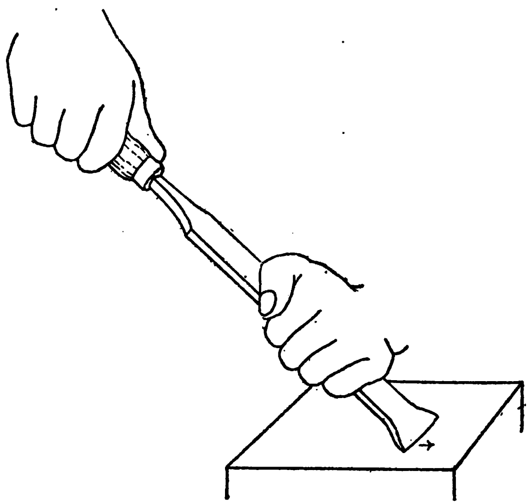


FIG. 152
Using the Scrape.

In the final stages of scraping, it is not even necessary to use oil. If the surfaces are wiped clean, and then merely rubbed over one another, the points of contact will be indicated by bright spots produced by the friction of the surfaces.

The form of scrape used for internal vee'd edges is made diagonal, or "long cornered," to go into the undercut portion of machine slides (p. 17).

The scrape is operated in all directions indifferently, and lighter and heavier according to necessity. What is termed *frosting* is done for good appearance after the surface is trued up, the scrape being traversed in crossing diagonal lines, and as if on an axis as it traverses, producing the appearance so well known on the slides of all high-class engine work and machine tools. Even when fine frosting is not done, it is usual to finish the latter stages of all scraped work with crossing diagonal lines, thus giving to the surface of the work a chequered appearance.

But other surfaces besides those that are flat are corrected by means of the scrape. Thus, in the best work, all shaft journals and axles are fitted to their brasses by scraping. And this is done, even though there is a little slackness or play allowed between them. This is especially important in journals and axles running at a high speed; because if they once begin cutting and scoring out, through lack of good contact, there is never any knowing where the mischief will end, and the durability of the bearings will be much diminished. But if a perfect contact is produced by scraping, the oil used in lubrication forms from the beginning a film of equal thickness, interposed between the shaft and brasses, and prevents heating and initial cutting out of the bearings.

Bearings, &c.—To scrape brasses or bearings, the shaft or axle itself is smeared with red lead, and rotated slightly with the hands in the brasses, the rotation making only a small arc of revolution—say a sixth or an eighth. The shaft is then removed, and the points of contact which the shaft made with the concavity of the arc are scraped out with the scrape, held as shown in Fig. 153, the edge *a* being engaged in scraping. The bearing is then wiped out to remove all particles of metal and to clean the surface

in readiness for the next trial-in of the shaft, and so on until good contact is obtained.

The most perfect steam joint is made only by scraping. Covers and cylinder ends are properly scraped after being turned. A film of red lead in oil suffices then to make a perfect joint. In the absence of scraping, with turned faces, a coil of copper wire, or a sheet of wire gauze, or of American cloth, and red lead are used.

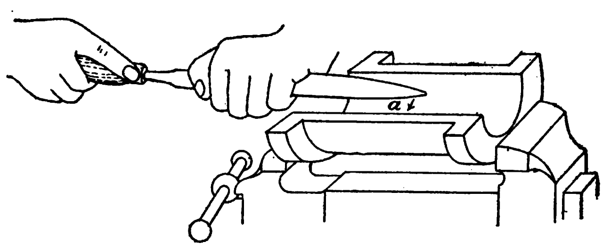


FIG. 153
Scraping a Brass.

Non-plane surfaces.—There is little trouble experienced in the formation of convex and of concave surfaces. The following few hints will be sufficient:—

Convex surfaces, when roughed down by chipping, are chipped along, not around, the curve. Concave surfaces, when external and not enclosed, when roughed down by chipping, are not cut with hollow chisels, but with the ordinary straight ones, and the chipping takes place round the curve.

When filing concave curves the file is not thrust straight forward, but is invariably moved diagonally—that is, the movement is a component of a forward thrust and a transverse curved movement. By this means the tendency to form a succession of hollows and ridges with a file having

a curve quicker than the curve to be filed is corrected. So in filing convex curves the file is moved diagonally, with a twist of the wrist, to avoid the formation of flats. When filing curved surfaces, the hands and wrists learn almost instinctively to move in unison with the curvature of the work. When filing a straight curve, the motion is compounded of a forward and of a diagonal motion; the movement of the wrists is, therefore, a twist. When filing a spherical surface, like the ends of bolts, the motion is that of arcs of circles. In these ways angularities and flats are avoided, than which nothing looks so bad in work whose surface should reflect the light in a regular sweep.

When filing curved surfaces or bevelled edges, it is not sufficiently accurate to mark the required outlines upon the ends of the work, and file down to them. It seems a simple matter to file down to lines, and then cross from line to line on opposite edges. But this will not produce accurate results. We must apply tests to the surface of the work, just as in the case of surfaces that are undergoing the operation of being levelled—that is, a sheet-metal templet, with an edge filed to the cross section of the work which is being outlined, should be used, concave, or convex, or bevelled, as the case may be. Red lead should be used with it, just as with straight-edge or surface plate.

Draw filing.—In what is termed draw filing or *poker filing*, the file is held at right angles or across the work, and moved, not transversely, but only up and down (Fig. 154). The object of this is to smooth over and obliterate the scratches left by the file when crossing the work transversely and diagonally. Scarcely any material is removed in this way, as the teeth do not cut in the proper sense, but scratch merely. Draw filing is useful in another way.

The smaller the area of a flat surface the more difficult it is to correct the tendency of the file to make it convex. To use the point of the file is not a satisfactory method. It is better in these cases either to draw file at the finish, or else to place several parts identical in form side by side, and file the whole at once. Draw filing is best suited to work which is somewhat long relatively to its width. But it is not well adapted to pieces that are short as well as narrow, because there is then so little length available for

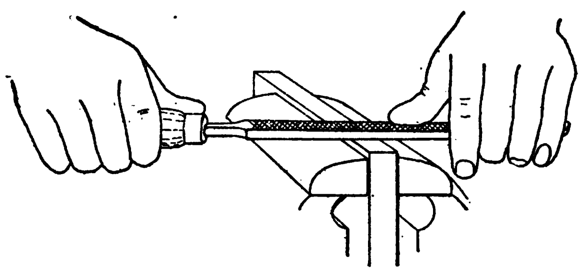


FIG. 154
Draw Filing.

the travel of the file. But when these pieces can be strung together, then they present the advantage afforded by a narrow surface of considerable length. Thus, nuts may be screwed face to face on a mandrel, and their flats filed off together; or small glands, having hexagonal flanges, may be driven with moderate tightness on a turned mandrel, and their flats be filed off together. The same kind of advantage is gained by casting similar parts together with a stem. Two small slide valves, for example, may be united endwise with a stem, and their faces and edges filed off together, and the valves be afterwards parted off with a hack saw. In filing very small and narrow gear-

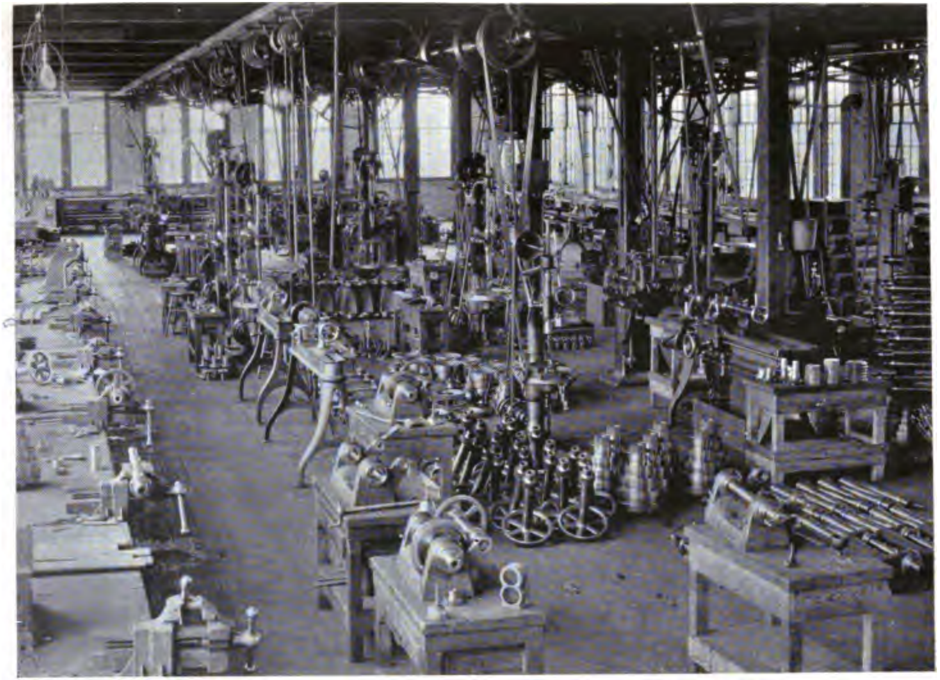


PLATE 4.—Shop of Hendey Machine Co., Torrington, Conn., U.S.A. [*Facing p.* 192.

wheels for models, a length sufficient to cut two or three may be filed, and the wheels parted off afterwards.

General remarks.—With a few general hints applicable to all classes of filing we may conclude this section of work.

When the grain of timber is opened out by sawing and planing, some amount of curvature and distortion almost invariably occurs. The same thing takes place in a lesser degree in metal, so that all relatively thin and slender work that is to be got up accurately, and from which material has to be removed in considerable quantity from all or most of its surfaces, should be roughed out in the first place before any portion is quite finished.

As a rule, when there are broad and narrow surfaces on a piece of work, the proper course is to true up the broader face or faces first, and from these check and true up the sides or edges.

The surface of much filed work is finished with emery cloth or emery paper. Just one layer is folded tightly round the file that happens to be in use at the time, so that the paper is as flat as the file itself.

Care of files.—Never use a file, unless an old one, upon the outer skin of a casting, for that will spoil it at once without any advantage being gained. The usual practice is: (1) to chip beneath the surface when the allowance is sufficient in amount; (2) to grind the skin off if the casting is small, and the allowance but slight; (3) in work turned or machined, to take the first or roughing cut deep enough to go well beneath the skin. In large work it is well to allow a little in excess rather than an insufficient or bare amount. In the latter case the tool has to scrape at the surface, and this takes more time in the long run, and is more destructive to the tool point, than as though

it penetrated well beneath the skin at once, to the soft metal beneath.

But in small and delicate castings, which have to be tooled by hand, the allowance of $\frac{1}{8}$ in. or thereabouts for machining cannot be given without entailing much labour. Moreover, there is risk of distortion or of fracture happening when small castings have to be chipped. It is better then to resort to grinding in positions where the grindstone or emery wheel can be brought to operate. And where the shape of the casting is such that this is not practicable, then the only way is to resort to the old-fashioned method of pickling in dilute sulphuric acid—say, four of water to one of acid—allowing the castings to soak for about half a day. Or heat the casting in a mixture of bone ash and coal dust, or sand, and allow it to cool down in the mixture. Similarly, when there is a hard skin to be removed from a casting or forging, and for some reason or another it is not convenient to chip, or grind, or pickle it, then the edges of otherwise worn files can be utilized with advantage for the purpose.

New files are used, first on brass or gun metal, then on cast iron, lastly on wrought iron and steel. This is a matter of economy, for partly-worn files will not cut the slippery brass, while they will *hang to* or *bite* the wrought-iron or steel.

When files are used much on wrought iron and mild steel, particles of the metal become stuck in the teeth and clog their action. The files are then said to become *pinned.* Card-wire nailed upon a board furnished with a handle (Fig. 155, upper figure) is used to clean the teeth from such accumulations. But many of the particles cannot be removed by the card-wire, and these must needs be picked out individually with a bit of pointed metal, such as soft iron wire ground to a point. A flattened wire

like that in the lower part of Fig 155 is also sometimes used. It is flattened under the hammer, and serrated by drawing it heavily over the file teeth. It is, therefore, desirable as far as possible to prevent accumulations of such particles in the file teeth. The practice is to rub chalk over the teeth, and, in the case of the finer files, a little oil, when used on wrought iron and mild steel, and non-crystalline metals and alloys. Cast iron and brass do not pin the files to any great extent. Wrought iron and

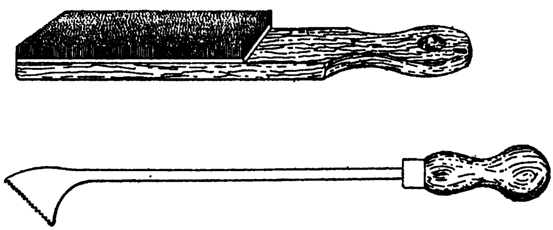


FIG. 155
Card-wire and Scraper for Cleaning Files.

mild steel do so. When, therefore, using the fine files, though not the coarse ones, on wrought iron and steel, a little oil may be advantageously dropped upon them, and this causes them to work more smoothly without becoming pinned, and without scratching and tearing up the metal. The finer files are more liable to become clogged than the coarser classes, and, of course, are correspondingly more difficult to clean.

In heavy filing it sometimes happens that the handle will slip out of the tang, and the hand, coming in contact with the latter, will receive injury. For this reason the files should always be driven deeply into their handles, but not right up to the end of the tang either, as they will then probably work loose in a short time. The hole in

the handle should not be burned, but bored first with a gimlet, and enlarged with another gimlet, or with a taper reamer. A softish wood, like poplar, willow, or elm, is better than a hard wood, like birch, beech, or oak. The

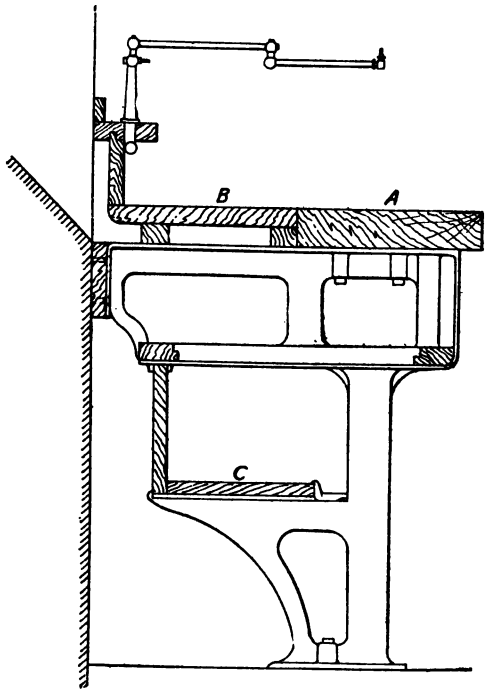


FIG. 156
Bench.

proper shape of the handle is seen in Fig. 11, p. 15, being globular, and not pointed at the end.

Benches.—Two types of benches with cast-iron standards are illustrated in Figs. 156 and 157. The front portion of Fig. 156 is formed of a thick plank A with a thinner

one B behind, and a handy shelf C is placed below. Provision for securing the vice is made by bosses and bolt holes at the front. Fig. 157 shows two standards somewhat like that in the previous Fig. 156, bolted together to form an independent bench. The wooden top is formed of thick planks laid lengthwise, with a hard wood (usually maple) facing laid transversely. Lower shelves and vice-bolt bosses are included. A drawer, sliding on angle runners, is slung underneath each workman's place. Messrs. John Lang & Sons, of Johnstone, use benches of this type throughout their works.

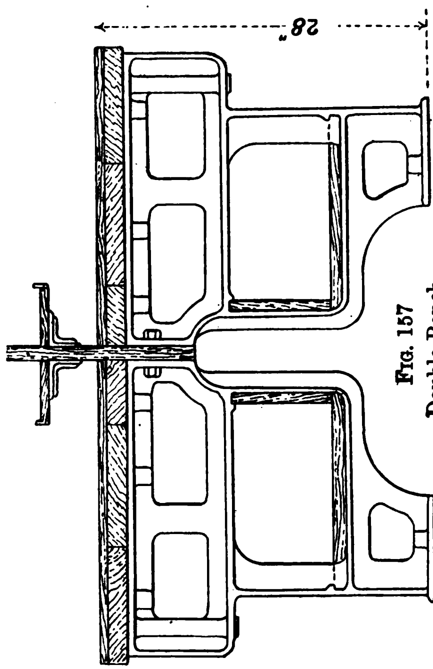
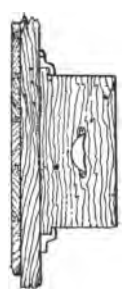


Fig. 157
Double Bench.



Vices.—The instantaneous type of vice has grown much

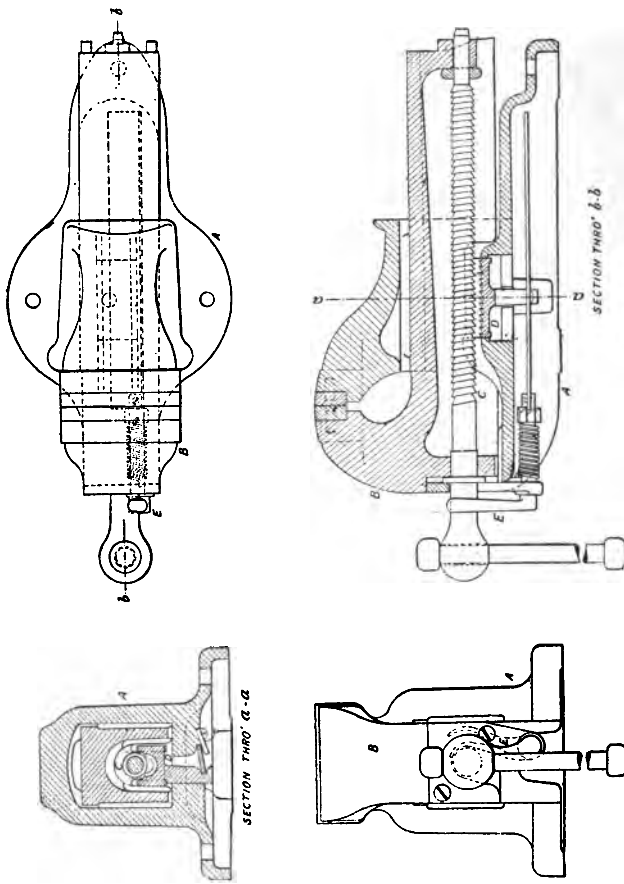


Fig. 158
Instantaneous Grip Vice.

in favour. One of the best-known designs is that made by J. Parkinson & Son, of Shipley, Fig. 158. Here the body A receives a sliding jaw B, moved by turning a screw

C, having buttress threads, engaging in a half nut D. The latter is movable, and may be thrown down out of engagement with C, by clasping the handle E to the knob of the screw, thus turning a flat strip partly around, and pulling down D. In this state the jaw B is free, and can be pulled quickly in and out. Then on releasing E again, a spring adjacent to it turns the flat rod, and pushes D up again, so that the screw is operative, and the vice can be used just as though it were a screw vice.

Vice work.—There is some art, and much caution, needed in the holding of work in the vice. Work which is slight

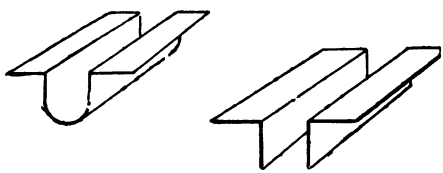


FIG. 159 FIG. 160
Vice Clams.

and wanting in rigidity, curved, or otherwise irregular in outline, requires delicate handling and cautious treatment. In these cases the difficulty of proper clamping often arises; there is risk of distortion and fracture to be avoided, in addition to the difficulty of filing into correct form. A certain proportion of fitters' work belongs to this type.

Clams.—To prevent bruising, vice clams are used. These consist of sheet metal, like Figs. 159, 160. The first is employed for heavy shafts, and solid circular work of that type which lies in the concavity of the clam, and cannot therefore become loosened and fall down out of the vice. The second is used for all other classes of work,

Sheet iron is generally employed for the first, sheet lead or copper for the second.

A serviceable type of clam is shown in Fig. 161. This is made of sheet brass or thin steel, and to it are screwed jaws, A A, of lead, or copper, or wood, which are easily taken off and removed when they have become bruised and scored with use.

Filing blocks.—Many small pieces of work are not clamped in the vice at all, being more easily manipulated while pinched in a hand vice held in the left hand. But to

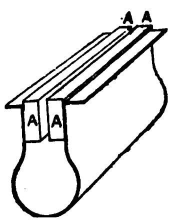


FIG. 161
Vice Clam.

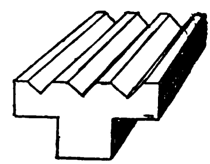
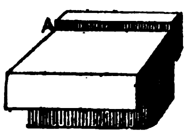


FIG. 162
Filing Block.

support the work while being filed, a plain little cubical block is pinched in the vice, and the work rests upon and is supported by it; and is prevented from undergoing displacement by the left hand. But filing blocks are made of various shapes to suit the work. A common type for general use is that in which vee'd grooves are made, like the grooves in an angle board, Fig. 162. The grooves being of various sizes, will admit slender work of various sections which will lie in the groove most suitable for it, and cannot then suffer displacement, however great the pressure of the file. Another form of block is shown in Fig. 163. This is used for filing flat work, which bears against the shoulder A.

The blocks in these two figures are shown with stems for holding them by in the vice. When of small size, the two blocks can be combined in one, the flat on one face, the grooves on the other, and no stem be added, the vice jaws embracing the body of the block. They may be made also either of wood or of metal, the latter being preferable because it conducts away the heat generated by filing.

For very thin plated work, and sheet metal, a filing block like Fig. 164 is used. The block is of wood, with or without a stem. The work is prevented from movement



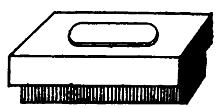


FIG. 163 FIG. 164

Filing Blocks.

by means of tacks or wire driven into the block close around the edges of the work, so that it cannot move, and slightly below its surface; according to the amount of pressure used in filing must the number of encircling nails be multiplied.

Pinching work.—It is necessary to exercise caution when pinching work in the vice for filing. Much work is spoiled by apprentices, simply through want of care in this respect. Delicate pieces require delicate handling. To pinch these in haphazard fashion in the vice must in most cases either distort or break them. If of soft metal, the former will happen; if of brittle, the latter. It is easy to prevent work from becoming bruised, but not so easy to prevent its distortion and fracture. One would think, to see how men sometimes bolt and pinch work to machines and

in vices, that metal is quite rigid instead of being elastic and ductile. Much light work when machined or filed turns out to be inaccurate, solely in consequence of undue pressure having been exercised in clamping it.

The ordinary tail vice with jaws opening radially should never be used for fitters' work. Always one of the vices with parallel jaws should be used to grasp it in a parallel fashion.

Take a small bevel wheel or pinion, Fig. 165, the teeth of which have to be filed either from a blank, or for the purpose of easing and smoothing those cast from a pattern, or cut in a machine using rotary cutters. There is no

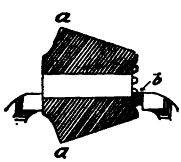


FIG. 165

FIG. 166

Method of Holding Bevel Wheel in Vice.

portion of this wheel that can be pinched firmly and safely in the vice. The only ways are these :—Pinch against the corners of the teeth at *a a*, interposing stout vice clams of lead or of copper. These will prevent bruising of the teeth, but the grip will not be firm. The other way is that shown in the same Fig. 165, where the pinion is pinched in the vice with its axis in a horizontal position, and a piece of packing is inserted at *b* to keep the vice away from the ends of the teeth there, and so prevent them from becoming bruised. If a large quantity of material has to be removed, as in chipping and heavy filing, this is the firmest way in which the casting can be held.

For the finer filing, and especially for that nearest the

small ends of the teeth, the method shown in Fig. 166 is more suitable. A is a mandrel of hard wood or iron driven into the shaft hole in the pinion. The mandrel is pinched in the vice, and the back of the pinion rests upon the vice jaws. Held in this way, and the filing being done in the manner shown in the figure, the pinion cannot become shifted in the vice, neither can any portion of it become bruised.

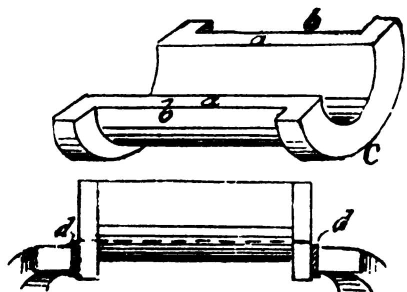


FIG. 167
Method of holding Half Brass in Vice.

Take a half brass, Fig. 167, which has either to be filed across the joint face *a*, or to have oil grooves cut in its concavity. There is only one proper way of holding such a casting. It must not be pinched across the sides *b b*, or the bearing will be squeezed inwards; and it must not be pinched upon the extreme edges *c* of the flanges, or they will become squeezed inwards. The proper way to hold the brass is as shown in the lower figure, in direct line with the mass of metal, where pressure cannot cause distortion, and even then it is always better to interpose narrow slips of sheet metal or wood, *d d*, between the vice jaws and the faces of the flanges, because otherwise some pressure will be put upon the extreme edges of the flanges, and tend to distort them.

To hold small engine cylinders properly requires care. It is annoying to expend a considerable amount of work on these and then at last to distort or fracture a flange through want of care in holding in the vice.

If any work is being done on the port faces, the cylinder, when small, should be clamped either across the cylindrical body, or over the flanges. The body may be pinched directly upon the metal, or blocks of wood may be interposed. When the jaws of the vice are of greater length than the length of the cylinder over the flanges, the blocks will have to stand out far enough to allow the flanges to be within the vice jaws. Also, the blocks may be hollowed to the curve of the body. This is the safest and most secure way of fixing.

If the cylinder is clamped across the flanges, the jaws must always be made to bite in line with the body, similarly to the brass in Fig. 167, and some soft substance, as wood, lead, or copper should always be interposed; otherwise the flanges, even though previously faced, will stand much risk of becoming broken off. The surface of a vice jaw is roughened, and the least extra pressure of the rough surface on one portion of a flange unduly strains it. The soft substance which is interposed yields before the extra pressure, and so saves the flange.

But cylinders of moderate or large size cannot be so held in the vice jaws, and must therefore necessarily be gripped by the web of a single flange only. This is so risky, that particular caution must be exercised to relieve the flange of all stress, except that due to the mere pressure of the jaws. That is, the flange must be relieved of all weight of the body of the cylinder which hangs over the vice jaws. This is effected in two ways—either by using a supporting prop of wood underneath the free end of the cylinder, or by slinging the free end in a chain from a crane or beam overhead. Held in this way, there is little risk of fracture.

To hold tapered work, tapered strips of wood are used,

as in Fig. 168, which shows a key, A, secured in the vice with the piece B, the taper of which is the same as that of the key. Vices are often made with swivel jaws to hold tapered work.

Word blocking is very extensively made use of for holding work during filing. Those faces of the blocking which go next the work may be flat, or vee'd, or curved, or bevelled, according to circumstances. In the case of any circular cylindrical piece of work held vertically (Fig.

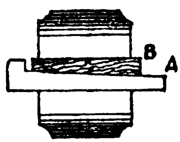


FIG. 168
Method of holding Tapered Work.

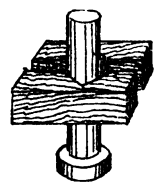


FIG. 169
Use of Wood Blocking in Vice.

169), it is obvious that the vice jaws alone could not hold it firmly, because it would pivot upon the narrow lines gripped by the jaws. So that, apart from the question of protection from bruises, it is necessary to introduce packing. The proper packing to use is the vee blocks. These need only be roughly sawn. In Fig. 170 an engine crosshead is shown gripped with similar vee blocks.

Another illustration of the use of wood packing occurs in Fig. 171. A is a slide valve, which is too deep to be pinched in the central part of the vice; but it has to be grasped towards one end, in order that the body of the valve shall pass down beside the vice screw. When pinching work in this fashion the corners at *a* are very apt to become broken off, because the loose jaw *b* of the vice, especially in the case of an old worn vice, or one which is

loosely constructed, takes up an angular position instead of one perfectly parallel in relation to the fixed jaw. In such a case, therefore, wood or metal packing should be inserted, as shown at *c c*. The pressure of the jaws is thus prevented from coming upon the corners at all. The work is also held with a better grip.

We might go on selecting illustrations from light levers,

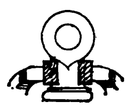


FIG. 170
Method of holding Crosshead.

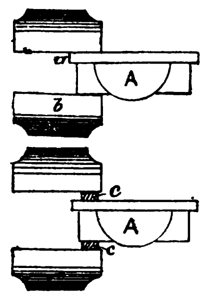


FIG. 171
Method of holding Slide Valve.

curved rods, some forms of cams, springs, light copper pipes, small fly wheels, and portions of mechanism partly fitted to one another. But enough has been said to impress on the mind the necessity of special care when specially delicate work is being handled.

The formation of slot holes.—Narrow slot holes are required chiefly for cottars, sometimes also to receive tenons. They occur mostly in those eccentric shafts which are fitted with cottars to their rods, in engine connecting-rod ends, in pump-rod connections, &c. They are usually parallel in one direction, but sometimes parallel, sometimes tapered in the other—that is, in the width. Sometimes holes of this kind are tapered in each direction, as in the case of detachable handles fitted over the ends

of screws for operating slides, handles for winches, &c. In workshops, these narrow slot holes with parallel sides are drilled out with a revolving, traversing slot drill, traversing in a horizontal plane, or with a narrow chisel-like tool, taking a succession of vertical cuts in a vertical plane, being actuated by the arm of a common slotting machine. Hence there are numbers of apprentices who never do such a job by hand unless in the course of model work done at home. A few directions about these matters may, therefore, serviceably occupy a few pages of this work.

There are a good many ways in which rectangular holes

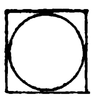


FIG. 172

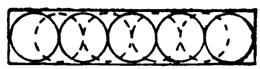


FIG. 173

Forming Rectangular Holes.

can be made. In the shops, a square hole is made by drilling, followed by a vertical slotting tool. An oblong hole is either made similarly, or by means of a slot drill traversing from end to end, and fed deeper and deeper, the ends being left either curved, or else slotted square subsequently under a vertical tool, or the holes may be punched roughly by the smith, and finished with a file or drift. When done laboriously by means of drill and file, the following are the details of the operation.

A square hole of small size is made thus: A round hole is first drilled, nearly, but not quite, equal in diameter to that of the square hole, Fig. 172, and the metal left in the corners is filed out until the square form is roughly attained. Now the really difficult work begins, supposing the hole is required to be very true. It is not at all easy

to file the faces not only perfectly straight through, but also square with each other, and with the faces of the work, and to bring the angles up keen.

To insure that a hole of this kind shall stand at right angles with the faces of the work, it is desirable in all but the shallowest webs to line out the square hole upon the opposite faces, so that there shall be no need to resort to continual trial with the square during filing, and the whole attention can then be given to the other matters. To file perfectly straight, it is not enough to merely thrust the file backwards and forwards, and remove material without attention to other details. As neither diagonal nor draw filing can be resorted to, it is very desirable that the piece of work should have some freedom of movement, to permit it to follow the slight curvature insensibly communicated to the file by the hand of the operator. Thus, in some cases, the work might be pivoted by the ends; in others it might, at least in the later stage, be held in the left hand, and the file be operated by the right. Or it may be secured to a block of wood that is pivoted freely When these devices cannot be resorted to, the point of the file must be frequently used alone, its action being localized about the central convex portions of the hole. In this way all four sides must be made as straight through as possible, and tested for longitudinal accuracy with the blade of the square.

At the same time, also, attention is given to the angles or corners of the hole. A hole filed with a square file, or with a flat file, cut upon each face, will not be quite square in its angles, but will be slightly rounding, because the teeth at the corners of the file are not absolutely keen. If, therefore, a hole is required absolutely sharp

in the angles, as if left by a cutting tool, a safe-edge file, or one having the teeth removed from one face by grinding, is the proper tool to make use of. It may be even desirable to remove a little extra from the smooth face of an ordinary safe edge by grinding, so as to bring the teeth up perfectly keen at the cutting edge. In this way, using keen-edged files, holes can be filed very sharp in the angles.

To file an oblong or slot hole true is rather easier than to file a square one true. First drill a number of contiguous holes, and connect them by filing from one to the other; or, since in narrow slots it is difficult to start filing with any appreciable effect from a small, round hole, another plan may be adopted. Drill contiguous holes, and fill them up with plugs of metal, and drill similar holes between each; then drive out what is left of the plugs. The way will then be clear for the entrance of a thin file, to be followed by the larger sizes. In Fig. 173 the holes first drilled and plugged are shown in dotted outlines, and the second series in full lines.

Drifts.—Formerly the cutting drift was a tool very widely used by fitters. It is still of service in some cases. There are several forms of drifts, and they have this advantage, that by their means holes of any form, after having been roughed out with chisel and files, can be finished with a high degree of accuracy, and also any number of similar holes can be thus finished.

Filing holes of any form accurately is always a very tedious process, and, therefore, in the absence of a slotting machine, the drift or broach affords the advantage of accuracy and expedition combined.

There are shallow blank holes, and there are thorough-

fare holes; and there are smooth drifts and serrated drifts. Drifts are also made of square, oblong, polygonal, and elliptical sections.

The square hole which we have been bringing into shape with the file might be finished much more expeditiously and more accurately with a drift. It would not pay to make a drift for one hole, but it would for a few such holes. The simplest drift would be a squared bar of steel, highly tempered at a dark straw or a purplish tint, and smooth upon its faces, Figs. 174, 175. If the hole is blank, a drift like Fig. 174 might be used—that is, square at the ends; but it is not the best form, because a square-ended tool does not cut so sweetly as one that operates on a diagonal edge, and therefore in detail, like Fig. 175.

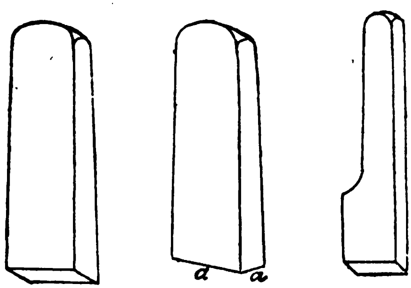


FIG. 174 FIG. 175 FIG. 176
Smooth Drifts.

Fig. 174, however, cuts on all four edges at once, Fig. 175 on the two faces *a a* only. Fig. 175, therefore, can cut two faces only of the hole at a time, and has to be turned a quarter or half way round in the hole after each operation, to cut the other faces in succession. In the case, though, of the drift (Fig. 174) which cuts upon each of its four edges, it is better to drive it through its hole four times, turning it a quarter round after each drifting. This turning round serves to correct any slight inaccuracy due to the drift itself. Both drifts are slightly tapered backwards above the cutting edges to give a very slight

angle of clearance, and so diminish friction, which is very considerable when all four edges are cutting at one time.

Blank holes are more troublesome than thoroughfare holes, because of the difficulty of cutting clean to the bottom, and of knocking back the drifts after having driven them down. The square-ended drift (Fig. 174) will cut clean to the bottom of a blank hole at last by removing the drift several times in succession, and clearing out the chips from the hole. The diagonal drift will not go quite to the bottom; but the hole must be finished, if it is necessary to have it perfectly clean and squarely cut to the bottom, with a chisel. As all the chips are driven forward before the drift, it may be necessary in many cases to remove the drift several times to clear the chips out. And, in fact, if much material has been left in the hole to be drifted, it is very probable that the drift will stick dead fast in the hole, and it can then only be driven farther at the imminent risk of becoming snapped off by the force of the hammer blows, and then, if the hole is not a thoroughfare hole, the trouble is nearly as great as having a tap or drill broken off in a hole. So that hard driving—that is, driving beyond the point when the drift does not yield freely to the hammer blows—should always be avoided. The drift should then be withdrawn, and the excess of material removed with a cold chisel before the drift is reinserted. To remove a drift from a blank hole, it should be tapped gently upon each side in succession to loosen it, the blows being given in horizontal lines, or rather slightly diagonally, inclining upwards, until it becomes sufficiently loose to be pulled out of the hole.

Drifts of the form shown in Fig 176 are employed both for blank and for thoroughfare holes of short length. It does not possess the guidance of a larger drift, but is

serviceable for holes of no great length, and also for preparing a hole to be completed with a long drift. The efficiency of the cutting edges of these drifts is maintained by occasional touching up of the end face upon the grindstone.

Serrated drifts.—Drifts with teeth are more troublesome to make than the smooth ones. But if made accurately—not otherwise, however,—they operate more sweetly and expeditiously than the others, acting on the same principle as milling cutters, or of files—that is, by the operation of a multitude of cutting edges. Serrated drifts have the advantage of better guidance over the smooth ones. The drifts in Figs. 174 and 176 have to commence cutting by the front edges immediately. Starting their holes thus, they cannot have the least power of self-guidance. Not until they have penetrated to some considerable distance do the holes they have commenced exercise any appreciable coercive or guiding influence upon the drifts. Even then it is not of much account, because of the tapering backward of these forms of drifts for the sake of clearance. It is therefore difficult to keep them true to their work. But the serrated drifts are usually tapered off at the lower end, and do not therefore usually begin to cut until they have been entered some little distance into their holes, and having partly entered, there is not so much difficulty in keeping them straight as there is in the smooth forms.

But in any case there is an initial difficulty in starting a drift truly. If the roughed-out hole is in the main out of truth, the drift is bound to follow it, and so finish it, out of truth. But if the main trend—if I may use the term—of the hole is true, then, if the drift starts correctly, it will finish correctly. Care must therefore be exercised to start the drift well, and if the drift shows a strong tendency to

go at an angle, to correct it by causing the force of the hammer to take effect in an opposite direction. This does not mean that the drift must be struck sideways, but that the resultant effect shall take place in a diagonal direction, opposite to that in which the drift is inclined to run. It will probably also be necessary to remove the drift a few times from the hole, and chip or file away the portions of metal that obstruct or coerce the proper course of the drift.

Two forms of square drifts are shown in Figs. 177 and

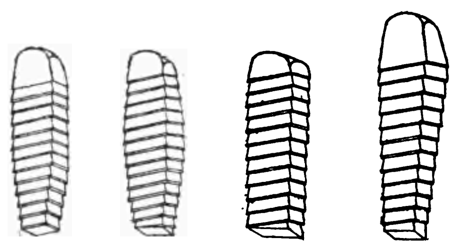


FIG. 177 FIG. 178 FIG. 179 FIG. 180
Serrated Drifts.

178. Fig. 177 is parallel for a portion of its length, thence it is tapered downwards for entering. It is also tapered above to allow it to pass freely through its hole. Fig. 178 is not straight tapered, but bellied, and its guidance is not therefore so good as that of Fig. 177.

If the smooth drifts require more care in respect of guidance, these require caution of another kind. For if much force is exercised, not only are the file-like teeth liable to become chipped and jagged, but there is much risk of the drifts becoming broken short off across the narrower section. To diminish the risk of this fracture occurring therefore, it is better, instead of filing the vees

quite keen with a three-square file, to impart a small radius to their roots with a small round file.

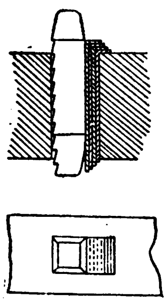
But supposing the number of holes to be drifted is considerable, and the drifts to be properly made, then these drifts operate with greater precision than the smooth drifts, leaving the work unmarked by ridges, and as smooth as though filed. But to produce these results they should only be employed for absolute finishing, and the bulk of the material must be first removed by other means, as by chisels, files, or smooth drifts. Or the hole may be formed by a succession of drifts if they happen to be in stock, each one slightly larger than its predecessor, and holes which are required very accurate may be finished with a serrated drift like Fig. 179, nearly, but not quite, parallel, being very slightly smaller at the entering end than at the leaving end.

As in the smooth types, when using these drifts, it is well, after driving them once through their holes, to turn them a quarter round, and drive them in again, and so on four successive times. In this way the drift acts as its own corrective, any slight inaccuracy in its sectional form being minimized, and the hole being rendered more accurate than it would otherwise be.

Taper drifts, Fig. 180, are very useful forms, being suitable for forming holes in the eyes of lever handles for various purposes. Driving them in to a certain distance only, insures that the holes shall be finished to a certain size. The blanks for drifts must be prepared carefully by planing or filing to the uniform cross section, perfectly straight along the sides. If otherwise, some teeth only will operate, the others remaining out of contact with the work. The teeth are then either filed or ground with a

milling wheel. Hardening also must be done carefully, the drifts being quenched perpendicularly.

In nearly every case the teeth lie diagonally. This is in keeping with one of the principles that underlie the formation and mode of action of most cutting tools—namely, that diagonal cutting, or cutting in detail, is more efficient, sweeter, cleaner, and requires the application of less force than cutting performed at once along the



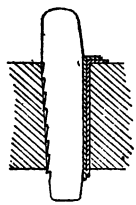


Fig. 182

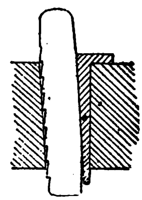


Fig. 183

Fig. 181

Enlargement of Holes by means of Backings.

whole breadth of an edge presented parallel with the material being cut.

Serrated drifts are often used for enlarging holes, and their sectional dimensions do not then correspond with the sectional dimensions of their holes, but a backing is inserted behind the drift.

Thus, in Fig. 181, an oblong or slot hole, such as a cottar-way, can be extended and finished by introducing successive backings, of various thicknesses, behind the drift. The face only of the drift is then formed with cutting teeth. A taper key-way in a wheel boss can

also, after having been roughed out with a chisel, be neatly completed with a taper drift, sliding against a parallel backing, as at Fig. 182, or with a parallel drift working against a tapered backing, as at Fig. 183.

An elliptical hole, or a long slot hole with semicircular ends, can be enlarged and finished with a drift, working against a backing of semicircular section, and as the hole enlarges, strips of sheet metal of increasing thicknesses, and bent over at the top to prevent them from being driven through with the drifts, are inserted between the drift and the backing.

Drifts of elliptical form are useful in some cases, and so in some unusual classes of work are those of hexagonal or octagonal sections.

Drifts are used without any lubrication on cast iron and brass; but they are oiled when employed on wrought iron and steel.

Drifting holes stresses slight work very much. This is of no consequence when there is plenty of metal surrounding the hole. But in the case of the eyes of levers, key-ways in slight key-bosses, cottar-ways in small crossheads, and in eccentric straps, and strap ends of connecting rods, there is a risk of distortion or of fracture occurring. In some cases where there is shaping to be done outside, this is better done after the hole has been drifted, so preserving all the metal possible to resist the stress of drifting. In other cases support can be afforded to the metal by pinching it in the vice during drifting. When no such support can be afforded, the drift should be used tentatively at first, being driven a little until it begins to be tight, and then removed, and those portions of metal that offer resistance to its passage chipped out. More preliminary work, therefore, will be done to relieve the stress

on the drift in slight work liable to become burst out or distorted, than as though there was an abundance of metal around the hole.

Making reversing levers.—An example in fitting is here given. The forms of these levers vary but the principle is alike in all, and Fig. 184 illustrates a common and convenient form. The act of grasping the small spring lever pulls the tongue out of the notch in the reversing plate, bracket, or quadrant; and the tongue is dropped into another notch on the letting go of the lever handle. The parts comprised are the main lever A, the tongue and bar B, the small lever handle C, the spring box D, and the spring within the box. The subsequent detail drawings are similarly lettered for convenience of recognition.

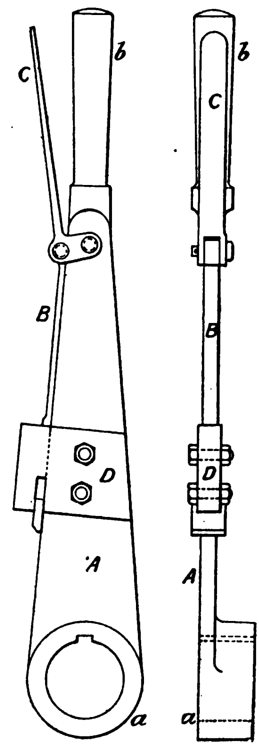


FIG. 184
Reversing Lever.

Having the parts all prepared in the rough, we commence the fitting up at the lever A. The whole of the work is either done on machines, or nearly all of it may be done by grinding and polishing. The hole in the boss *a* must be drilled, and can be done in almost any way, but on a drilling machine table is the most suitable, using a drill first and a reamer afterwards, and then a facing cutter.

The boss may be turned at the same setting with the bossing tool. For this work, using stamped forgings, grinding is often substituted. The handle end *b* is turned in the lathe in good work. But this also is often ground when stamped forgings are used, a rotary motion being imparted to the lever by hand while held against the emery wheel and buffing wheel. The web of the lever is either shaped across on faces and edges in a shaper, in a rather slow and tedious fashion, or it is milled, or it is simply ground and polished. Actually, therefore, the only part the machining of which is absolutely necessary is the bored hole in the boss *a*. All the rest, including the boss faces, may be finished neatly by a skilful grinder if levers are stamped. An exception is the edge on which the bar B slides. This must be filed and draw-filed true by a straight-edge or milled.

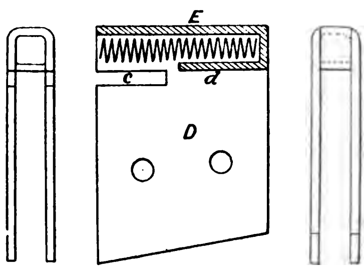


FIG. 185
Spring Box.

The bar B is next taken in hand, and the working parts finished to fixed gauges. The manner in which the finishing is done will depend upon the class of work and the practice of the shop. The faces and edges may be shaped, or milled, or filed. The width of the bar must be parallel, and of the same width as the thickness of the lever on which it slides. Edges and faces must be square.

The end of the bar, B, has now to be fitted to the spring box D, Figs. 184, 185. If the box is a casting, the recesses *c* to receive the tongue can be cast out with a

slight allowance for filing the edges. If a forging is used, then the slots must be marked and cut out. The slots *c* are marked off from the tongue by laying a straight-edge along the top and bottom faces, and scribing the boundary lines of the slots therefrom on the box. The slots are either sawn out or slotted. In either case a block of wood is thrust between the cheeks or plates, to keep them apart and to lessen vibration. The slots are cut first barely to width, to allow for a trifle of filing of the edges subsequently. A thin file is used, and the slots carefully enlarged until the tongue will slide within it.

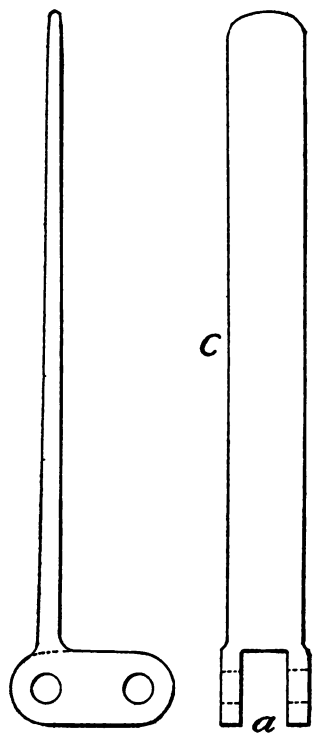


FIG. 186
Spring Handle Slotted.

The handle C, Fig. 184, having had its end forged solid, has to be slotted (Fig. 186) to fit over the lever A and the boss of the bar B, but the pin holes are not drilled through lever and boss yet, unless the number of levers required of a single size is so large as to pay for a system of templets. In that case, one lever having been fitted, templets are made from that, or the parts themselves are used as templets by which to mark off any number of similar parts. But in the present

example the assumption is that a few levers only are being made.

At the present stage the spring box is clamped (Fig. 187) upon the lever in its proper position just clear of the quadrant or bracket, and while in this position the holes for the bolts are marked and drilled, the burrs taken off, the bolts inserted, and the lower edge filed off flush with the lever.

The two portions of the sliding bar B are now taken. B and C, Fig. 184, are placed in position in relation to each other, and the hole for the top pin is drilled, then the tongue is put in position, two centre pops are made, one on each end of the bar, to suit a trammel, which is given to the smith for welding up by. After welding, the bar is corrected and finished truly over the welded portion ready to go into position for the drilling of the second pin hole. In order to mark this, the handle C is laid back close upon the main handle, and the tongue is pulled right back into the box D. Then the tongue B is lifted just a shade off from contact with the lever A, and the pin hole in the lever A is scribed off from the bottom hole previously drilled in the lever C. If, when the handle C was back on the lever handle, the pin hole were marked with the bar B flat on the lever A, then it could not be thrust forward into the position in Fig. 184. This is because the bar moves in a part of a circle with the lower pin as centre. If the hole were marked with the bar flat on the lever, the

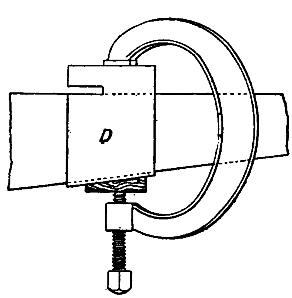


FIG. 187
Spring Box Clamped on Lever.

bar would not be able to move in this curve, since it would jam on the lever at once. The effect of raising the bar from the lever is also to lift the tongue in the spring box very slightly, and as this lifting would be more in a short bar, the amount of clearance when marking the pin hole must be more than in a long lever. A little easing will be necessary in the parts. When this is done the lever can be taken apart, and the parts polished on buff or on emery cloth, and then put together finally with the spring E inserted in the recess formed by *d*.

CHAPTER XI

ADJUSTMENTS

THERE are several important matters to dispose of now, which can hardly in strictness be classified under one head, and yet which have much kinship with each other. For the most part they embrace the methods of putting parts together after they have been prepared at machine or vice, and in a general way, therefore, we can best consider them under the general term or heading, *adjustments*. We can regard them as the minor operations of fitting, and as quite distinct from the major operations of erecting. In large workshops there is really little other work save that of adjustment done. So simple is this in many mechanisms, that youths are entrusted with the fitting of engines and machines of standard and repetitive types.

Fundamental conditions.—There are four terms expressive of conditions of the most cardinal importance, which lie at the very basis of all good fitting, or more precisely, perhaps, of erecting. These terms are *level*, *plumb*, *parallel*, *square*. They are simple, yet on the relative approach to, or departure from, the perfection of these conditions, much of the perfection and free movement of mechanisms depend. There shall be two pieces of work of identical design and construction. The machining in them will have been done at the same time, in the same machines; but they shall have been fitted

and erected by different men, and while one will work with delightful ease and freedom, the other will be hard, stiff and jerky, and become hot with excessive friction. The most excellent machining, and minute fitting with file and scrape, will not avail to prevent stiffness of working caused by inaccurate adjustment. First, therefore, we will run through some examples of how to get work level, plumb, parallel, and square.

As in lining out, so in the putting together and erection of work, centre lines are almost always worked to. And instead of the rule, the calipers, and gauges, and trammels are used to check centres and dimensions by. And

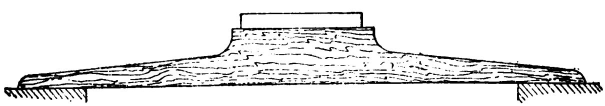


Fig. 188
Spirit Level laid on Straight-edge.

for testing the horizontal and vertical truth of work, the spirit level and plumb bob are in constant and chief request.

Spirit levels, when used across broad areas, must be placed on straight-edges—a favourite plan being to utilize a special form of wooden straight-edge, as in Fig. 188.

In the Starrett spirit levels, Fig. 189, the tube is adjusted by forming lugs at the ends, and raising or lowering these on vertical screws fixed in the base, by means of circular locking nuts. The spirit tube is encircled by a brass tube, which may be revolved to cover over the bubble portion and protect it. A short, vertical spirit tube is placed in the middle of the base, as seen.

The foundation of all work which has to be erected must first be levelled. This, of course, does not include very small work which is fitted together upon the bench, and for the fitting of which squares and calipers are mostly used; but it applies, without exception, to all the ordinary run of mechanisms which are erected upon the floor. The practice is to clear an area, and place such wood blocking as may be required upon it, and lay the casting or plated structure which forms the base plate, or foundation for the job in hand, upon the blocking; and block up and wedge the casting or plated structure until it

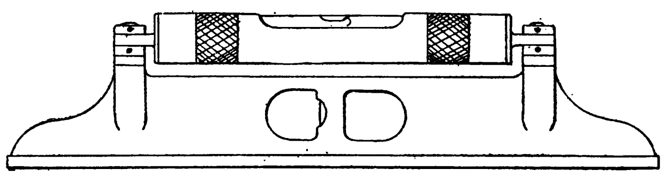


FIG. 189
Adjustable Spirit Level.

is level. The blocking used generally measures from about 8 in. to 14 in. or 15 in. square, or from 3 in. to 6 in. thick, and of the width of ordinary 11 in. deals. Different thicknesses are necessary to block up work at different levels. Besides these, thin bits of wood packing, and wooden and iron wedges are also used for precise adjustments for height.

If the surface of the base plate or the bed plate upon which the work has to be erected is entirely rough, then it is useless to try the level directly upon its surface. But a parallel straight-edge of iron or of wood must be interposed, and the level laid upon the top edge of that. By this device such irregularities as are present on surfaces which have not been machined are prevented from pro-

ducing misleading results on the level, the straight-edge lying across the entire face, and showing the horizontal position or otherwise of the general plane surface.

If the surface is very lumpy, the straight-edge will have to be wedged or packed up, as in Fig. 190, *a a*. On the first few trials the spirit level will indicate some considerable departure from horizontal truth, and first wedges and then packing pieces, of suitable thickness, will have to be driven between the under face of the base plate and the blocking in the positions where levelling-up has to be done. After a while this will have the effect of bringing the surface of the plate into its required horizontal

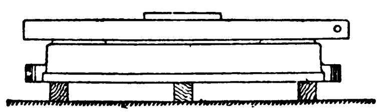


FIG. 190
Levelling with Straight-edge and Spirit Level.

position, as indicated by the level A, with the straight-edge tried in all directions—lengthwise, transversely, and diagonally; and from this position it will not be moved until all the superstructure has been erected upon it.

Such cases as this frequently occur when superstructural work is fitted to its foundation with chipping strips, and when wrought iron, plated, framed, and girder work form a foundation for machinery.

When the bed plate is provided with planed facing pieces, then it is generally sufficient to try the spirit level directly upon the surfaces of the various planed facings, and then wedge and pack up. Unless, however, the foundation work is quite rigid, and the machining or the chipping and filing done are quite true, it is better to carry a straight-edge right across over adjacent facings,

and try the spirit level, as before, upon the straight-edge, Fig. 191.

Bearings for shafts and axles need to be very truly in line. In many classes of work the adjustable bearings so

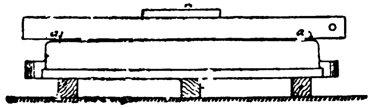


FIG. 191
Levelling with Straight-edge and Level.

frequently used for line shafting are not suitable. The usual practice when levelling rigid bearings is to lay a straight-edge along the concavity of the bearing seats, and try the spirit level upon the top edge of the straight-

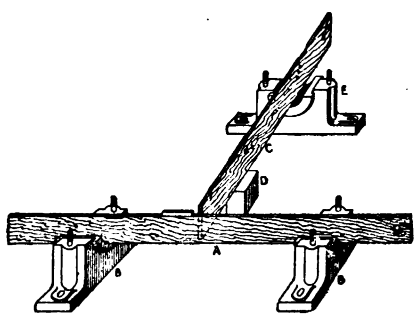


FIG. 192
Levelling with Two Straight-edges and Levels.

edge (Fig. 192, A). If the departure from horizontal accuracy is considerable, one of the blocks must be raised or lowered bodily, either by reduction of the foot, or by introducing suitable packing, dependent on the character of the job. If the departure from truth is minute, a little scraping of the concavity of the bearing will probably

suffice, in which case, the shaft or axle should be tried in, and the level tried upon that; that is, if the shaft has been turned truly along its whole length. If turned only at the journals, then thickness bits of parallel thickness must be placed upon the turned journals, and the straight-edge raised upon them, and the level laid upon the straight-edge (Fig. 193).

When three or more bearings, which are not in line have to be tried for horizontal truth, two straight-edges arranged as in Fig. 192 should be employed. One, A, is carried across the two bearings B B, which are in line; the

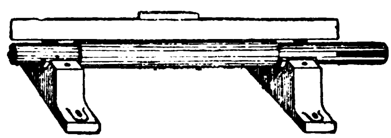


FIG. 193
Levelling a Shaft.

other, C, is carried from the bearing E, which stands, say, at right, or any other angle with B and B. The straight-edge C is packed up at D, until it is at the same level as straight-edge A, and the bearing E is raised or lowered until the spirit level set on straight-edge C shows it to be horizontal.

A good deal more trouble is experienced in levelling bearings upon wrought-iron plated structures than in levelling them upon cast-iron base-plates. There are, of course, no facing pieces on plated work, consequently all fitting to them has to be done with chipping strips. A good deal of adjustment, therefore, is often necessary before brackets and bearings are brought finally into their right positions. They have to be chipped and clamped, and tested several times over, and finally their bolt holes

are drilled with a John Bull, with the work clamped together in its exact place (Fig. 194) or with a portable machine.

When there are several shaft bearings in line, the detailed methods of levelling them will vary with circumstances. If the bearings are moderately close together, it is usual to first fix the positions of the end ones, and afterwards the positions of those which are intermediate. If the bearings are far apart, they are usually levelled in

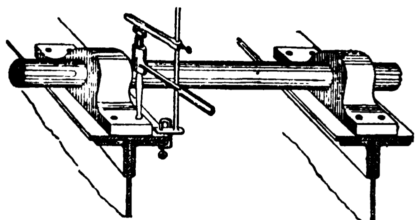


FIG. 194
Adjustment of Bearings.

succession, beginning at one end. The positions of bearings several feet apart upon very massive structures are occasionally fixed with a theodolite, and minutely adjusted afterwards with a level. But in general the methods adopted are as follows:—If the end bearings are only a few feet apart, which is the case in the majority of mechanisms, with one or two bearings intermediate, then the end ones are first brought to the same level by means of straight-edge and spirit level. The positions of the intermediate ones are settled afterwards, sometimes with the straight-edge, sometimes by putting the shaft in its bearings, and levelling-up shaft and bearings together. The first method is generally adopted when the bearings rest upon a base, or are hung from above; the second when they are bolted to the side of a structure—necessarily

so if the bearings are not divided, but are bored out in solid metal, or solid bushed. In the second case, where bearings are far apart, as in much heavy constructional ironwork, the position of one end or middle bearing is first fixed, and all the rest in succession, starting from that. Then a straight-edge is carried from the one whose position has been first fixed, and the position of the second is adjusted by spirit level. From the second the position of the third is similarly adjusted, and so on, until the series is brought into one horizontal plane.

There are some bearings whose positions do not admit of adjustment at all. They are of the "dead-eye" type—those, namely, which are bored out of solid metal in their own frames. When such solid-bored bearings are in separate castings, bolted to wrought-iron plated work, then they admit of adjustment with their shafts in place; but when bored in cast-iron standards and cheeks, no adjustment is possible after they are once bored. There is all the more need, therefore, why these should be lined out most accurately *from a base line*, which may be either the bottom of the casting, or a line scribed upon the casting parallel with the bottom, or the face of the marking-off table.

Sometimes the bearings are set by their shafts, and some of the labour of adjustment saved thereby. Thus, suppose there are two or more bearings to a shaft, the shaft will be put in place, and the bearings set by centre lines or plumb line, as the case may be, and the bolt holes through which the bearings are secured to their framing will be drilled while the shaft remains *in situ* (see Fig. 194). In that figure solid bearings are shown, but the method is equally applicable to divided bearings. After one hole in each bearing has been drilled and its bolt

inserted, the shaft is turned round in its bearings in order to try if it moves freely. If it is tight the bearings are tapped with a hammer, and their positions accommodated to the shaft before any more holes are drilled.

Hitherto we have considered only the horizontal levels of shaft bearings. But there is also the lateral alignment to be considered at the same time as that in the vertical direction. This is secured in one of two ways. When the centres of the bearings are not far apart, the trying-in of the shaft is usually sufficient to insure the truth of the bearings sideways. But if the bearings are a long way asunder, then the practice is to strain a length of fine copper wire of, say, 20 or 22 gauge, tightly over the two end bearings, and set the intermediate bearings by the wire. The wire will be usually strained along one *edge* of the bearings, not at the centres. Of course, it must be pulled quite taut, and fixed thus while the adjustment of the bearings is proceeding.

Then, further, the positions of shafts in *plan* frequently have to be at right or other angles with one another, involving a corresponding position of their bearings. Various methods are adopted for insuring the accurate setting and fixing of such shafts. If the work is small, it suffices to employ a square or a level for the purpose. But such a method is inadmissible for heavy work. The practice then is to set out the centre lines of the shafts upon the base of the work, employing the common geometrical methods for the purpose, and then plumbing down from the shafts to these lines; or, if their height is not great, and the base is a planed one, squaring up to the sides of the shafts in position, or to the centres of the bearings, with the shafts removed.

Again, the spirit level often affords the only means of

testing the parallelism of parts and shafts which are isolated from one another on the same mechanism, as shafts and other bearings on opposite sides of a structure, double cylinders, or guide bars bolted to base plates.

Plumbing.—To obtain parallelism in shafts that are not at the same level, the practice is to drop a plumb line from one, the upper, shaft (Fig. 195) already fixed, and take measurement A from the line to the side of the lower shaft.

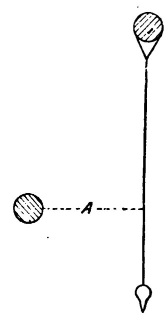


FIG. 195
Taking Centres of Shafts at different Levels.

The plumb bob and the plumb rule are no less important to the fitter than the spirit level. When a base is levelled, or shafts brought truly horizontal by means of a spirit level, then anything which is plumb is of necessity at right angles with the base or shaft. Bearings for vertical shafts are among the commoner illustrations that occur of the use of the plumb line. The centre of a bearing in the upper portion of a structure can readily be set to a centre line struck upon the base by the method shown in Fig. 196. As this figure does duty for two illustrations of plumbed work, we suppose now that instead of the lower bearing A there is simply a centre line scribed upon a base plate, over which the top bearing B has to be set. The hole in the top bearing is bridged with a strip of wood, and a small hole bored in its exact centre. Through this hole the plumb line is dropped and the bearing set, and its holes drilled in the position where its centre corresponds with the centre line scribed upon the base.

Also when two bearings have to be fixed one above another, the position of the upper one is usually fixed in the first place, and that of the lower one afterwards, as

shown in Fig. 196. The holes in both bearings are bridged with hard wood, and the plumb line dropped through a hole in the upper one, and the bottom one adjusted until the point of the bob is just upon the centre point of the lower one. Or the lower one may be first fixed, and the position of the upper one moved and adjusted until the bob is over the centre of the lower one, when the top one will be bolted in the position required, and so fixed.

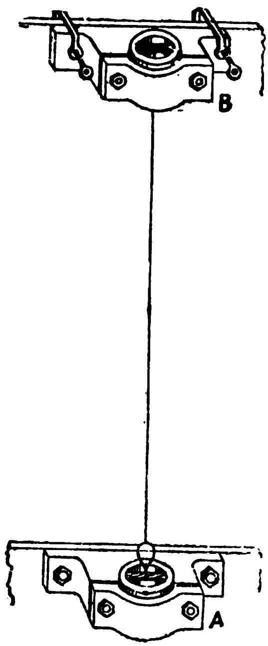


FIG. 196
Setting Bearings Plumb.

Another way to fix such bearings plumb, is to take off the caps and try a plumb rule on the concave faces of the bearings at back and sides in turn, and adjust them until the plumb bob and string fall exactly in the centre of the rule. Another way is to put the shaft into place and try the plumb rule against its sides. If the shaft is turned throughout, then the rule will lie close against it; if turned only at the journal ends, then parallel thickness pieces must be inserted between plumb rule and journal ends.

To set the central bearing of the A frame (Fig. 197) plumb over the centre of the pumps (not shown) which are bolted on the base, the plumb line also is used. The line is suspended from a piece of wood bridging the bearing, and the frame adjusted until the plumb bob is exactly over the pump centre line scribed across the

base, and when that position is fixed the bolt holes are drilled.

Again, to set the engine standards, in Fig. 198, the plumb line is held against the sliding faces A, A prepared for the crosshead, and their positions adjusted until they are plumb over the lines corresponding with the distance B, scribed upon the base plate, equidistant from the

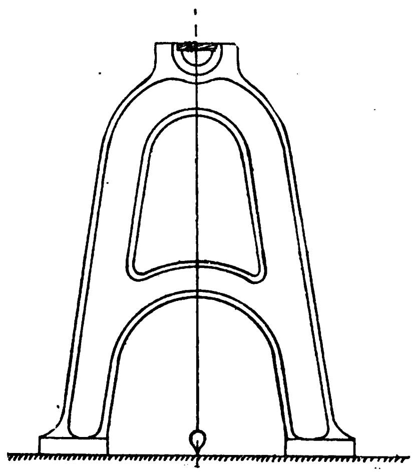


Fig. 197
Setting Bearings Plumb.

centre line, C, of the crank shaft. The vertical accuracy or otherwise of the faces, being of considerable length, must also be noted at the same time, and, if need be, adjustment made by easing the feet, D. This test may be made by the plumb line, or the plumb rule, or by the spirit level held vertically.

Single bearings set like those in Fig. 196 may be plumbed or levelled in one of two ways. The spirit level may be tried directly in the concavity, and the bearing

adjusted until the position of the bubble in the small end tube is central. Or the level may be tried flatwise upon the machined facing at the top, against which one of the shoulders of the brass fits; or, if the brass is in place, upon the flange of the brass itself. In good work which requires minute adjustment the bolt holes are generally

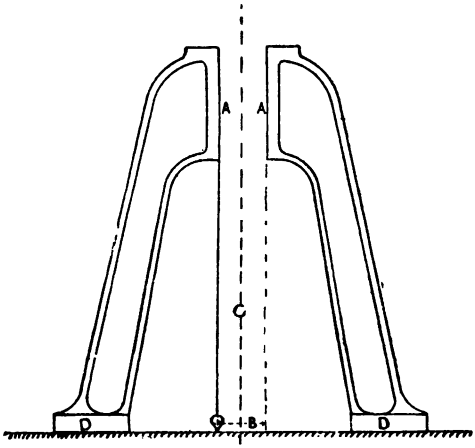


FIG. 198
Setting Standards Plumb.

drilled when the final adjustments have been made. The practice is generally as follows—

When cast-iron brackets have to be bolted to wrought-iron plates, the bolt holes are usually first made by casting or drilling in the brackets. After final adjustment of the brackets, they are clamped tightly to the wrought iron, and the holes are either drilled through directly into the wrought iron with a ratchet brace and John Bull, or the holes are marked through from those in the casting on to the plate, and the casting is then removed, and the holes

drilled in the plate. If cast iron goes against cast iron the holes are either drilled in the way just named, or they are drilled through bearing or bracket and main casting at once, through solid metal. Or they may be cored in each smaller than the finished size, by $\frac{1}{8}$ in. or $\frac{1}{4}$ in., according to the probable difficulty of adjustment, and reamered out together, while the parts are held in place with cramps. Only for rough work is it advisable to core holes $\frac{1}{8}$ in. or $\frac{1}{4}$ in. larger than their bolts, with the view to save drilling or reamering. Sometimes, however, when there are a number of bolts in a structure, some holes will be rough-cored for slack bolts, some will be drilled or reamered for tightly fitting bolts.

Parallelism.—The parallelism of parts is obtained in the main by the methods already illustrated. Two or more shafts can be made parallel in the horizontal direction by the use of the spirit level and straight-edge. Two or more vertical shafts can be made plumb with the plumb bob, plumb rule, or level. But much depends on size. The methods adopted for large, heavy work, are not suited to light work. For the smaller work it is not usual to employ the methods named, but calipers, straight-edges, and squares afford the most convenient means o making tests.

In such work there is usually a true base of some kind whence tests can be made. The base may be a plate of cast or sheet metal, a bottom casting, a standard, a framed structure, &c. Often the work is so small that it is easily manipulated bodily, and turned about into convenient positions upon the bench. Methods adopted for ensuring the parallelism and vertical accuracy of parts are as follows—

The parallel height of a small spindle or shaft from its

base is measured with a strip of wood or with calipers. A small cylinder will be set level by passing a straight-edge

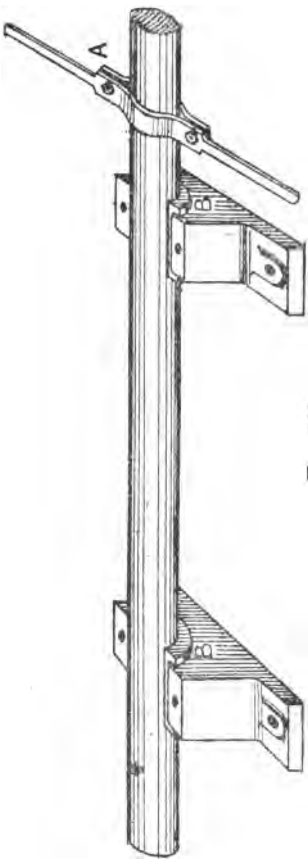


FIG. 199
Adjustment of Shaft into Bearings.

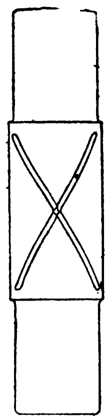


FIG. 201
Oil Grooves in Shaft.

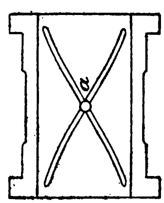


FIG. 200
Oil Grooves in Brass.

through the bottom of its bore, and measuring with calipers from the bottom edge of the straight-edge to the face of the base plate, or with a short distance strip. The distances between contiguous shafts or axles will be

similarly checked with calipers or distance strips, and the distances also between parallel guides.

Shaft adjustment.—When a shaft has been turned and its bearings bored, it seldom happens that the contact of the bored and turned surfaces is perfect. The turning and boring may have been done roughly, leaving minute ridges upon the surfaces. Or the bearings may not have been adjusted perfectly parallel with each other. Therefore it is nearly always necessary to fit the shaft into its bearings, and ease off a trifle of metal from the highest points of contact. The practice is as follows: The shaft is smeared with red lead mixture, and tried in its bearings, being rotated through a portion of a circle to transfer the colouring matter from its surface to the concave surfaces of the bearing. If the shaft is heavy in consequence of its own weight only, or because of wheels, &c., keyed upon it, it is necessary to obtain more power of leverage over it than that afforded by the hands. A lathe carrier is therefore fixed upon the end of the shaft, or a pair of clips, Fig. 199,A, and these afford the necessary leverage for the partial rotation of the shaft in its journal bearings, Fig. 199, B. On removing the shaft, the contact of surfaces is apparent by the transference of the red lead, and the superfluous metal is removed with the scrape. After the shaft has been adjusted in this way until contact occurs all over the surfaces of the journal, oil grooves are cut, unless the shaft is of very small diameter. The grooves are cut with a round-nosed chisel, and in the top half of the bearing. Fig. 200 shows this top half with its oil grooves. It will be observed that they radiate diagonally from the central oil hole, in order to distribute the lubricant well over the area of the bearing faces. Sometimes shafts are fixed in their journals with keys, and the wheels run

loose upon their shafts. Then the top portion of the shaft in that location upon which the wheel runs is provided with oil grooves, as in Fig. 201.

A shaft may be rotated without damaging it by simply putting a rope sling, as in Fig. 202, and inserting a bar or wooden handle, turning it backwards until the sling tightens and the shaft revolves. Sometimes a piece of sacking is wrapped around the shaft, and a chain sling used on top of this.

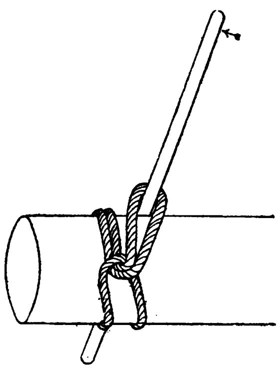


FIG. 202
Method of getting Purchase on a Shaft.

Another kind of adjustment is that of wheels keyed upon their axles, or their shafts. The fit in these cases is of a different kind from that in the former case. The first is a *working*, or *easy* fit; the second is a *driving* fit. Shafts must run freely, but in perfect contact with their bearings. Keyed shafts must also be in perfect contact, but without any freedom of movement. They must be so tight, in fact, as to require being driven in, or pulled on with strong pressure. Although shafts and the bored holes into which they enter are properly turned to gauge, yet there are often some slight inaccuracies which require to be corrected with the file. The gauges may fit too slack or too tight, the bits or drills, or tools used in boring, may leave minute ridges, the holes may not be perfectly circular, and these minute errors are very palpable in the mutual fitting of hard unyielding metals. It is not good practice, but it is nevertheless often necessary to effect

some correction with the file in shops where the interchangeable system has not been introduced. The bore of the wheel may have to be eased with the back of a smooth half-round file. Or the shaft may be eased by draw-filing —not much in amount, of course, but sufficient to enable one to be drawn or driven over the other. The fit must be tight, because no key, however well fitted, will prevent a slack wheel from "working" upon its shaft. And yet, if the fit is a little too tight, it is impossible to pull the wheel over its shaft without risk of fracturing its boss. There is an advantage, therefore, in easing the bore, and draw-filing the shaft in the direction in which the wheel has to be pulled on. Also a little oil should be rubbed on shaft and bore, to assist the sliding of one over the other.

To drive a shaft into a wheel, the blows should be given in perfect line with the axis, and *dead* or firm. If the blows are not in line, then the shaft, if slight, will become bent. If not dead, vibration may fracture a boss or arm if the casting is slight. There must also be a sensible *give* or yielding at each blow. If the hammer rebounds without causing the shaft to move, then generally the fit will be found too tight, and it is risky to drive any more without easing. Another thing is, that a steel-faced hammer should not be used upon the end of a shaft, because it will bruise and bend up the end. A hammer of copper or of lead is used, or else a block of hard wood, end grain on, is held between the steel hammer and the end of the shaft. In heavy work the hammer is of no use, but pressure is employed for pulling on wheels and axles; a hydraulic puller is employed for heavy work; and for lighter work, screw pressure, obtained by a couple of long bolts.

Fitting brackets.—The bolting of brackets and bearings of cast iron to foundations of cast and of wrought iron is a task that is constantly recurring in fitters' work, and calls for the exercise of some judgment. The ideal fastening is, of course, a turned bolt in a drilled or reamered hole. If parts are fastened together in this fashion, there can never be any slackening or working loose of the parts relatively to each other. But this is costly, and therefore only adopted absolutely in the best work. A modified method is to have a few *turned* bolts in *bored* holes, and a few *black* bolts in *cast* holes. The turned bolts suffice to preserve the work from working loose, while the use of black bolts in cast holes effects a corresponding economy. A third method is to have all bolts black and all holes cast, which is the cheapest, but the least satisfactory.

When fitting brackets with drilled holes to plated work, the brackets are held up by hand, if light, or slung in chains or ropes if heavy; and when their positions are fixed, they are clamped, and the bolt holes drilled both through the feet of the brackets and the plate to which they have to be attached; or if already drilled in the foot, then carried through the plate. If holes are cast, then a podger is inserted in one of the holes, to pull, and hold the bracket in place with; or a drift is inserted. Then the position of the bracket is tested, and other holes drilled, or existing holes opened out with a reamer. There is this great advantage of reamering, that when holes overlap one another, on the completion of necessary adjustments, the reamer being put through makes them fair in bracket and plate, and there is no need to file, or drift, or stress the material, or to have bad slop fitting between bolts and holes.

Drilling.—A large proportion of holes are drilled by

PLATE 5.—Shop of Mather and Platt, Ltd., Manchester. [*Facing p.* 240

the fitters, or, rather, by the fitters' labourers, at the bench, and upon work in course of erection, and this even though there are plenty of machines available. The reason lies in the necessity for adjustment of parts. The position of many holes cannot be fixed until after certain adjustments of dimensions and centres have been made in course of fitting and erection, and then, when the positions of the holes have been settled—the work being partly fitted or erected—it is cheaper to drill the holes by hand in place, than to take work apart and carry it to the drilling machine, or to take it bodily to the machine. Besides, hand drilling, especially when done by labourers, is not so costly as it might seem, especially in the case of holes not more than about an inch in diameter. Anyhow, there is of necessity a lot of such hand drilling, and reamering also, done, though the portable drilling machines have lessened it very much of late years.

The usual method by which holes are drilled at the work-bench, and in work in course of erection, is by the *John Bull.* The drill press is, of course, quite unsuitable, being fixed; the "Archimedean" drill is not powerful enough; portable drills are used for some classes of work; but for very much drilling done by fitters, the John Bull is still used. This is rigged up in various ways, according to the position of the holes that have to be drilled. The commonest method is shown in Fig. 203. A bar, A, having a stout foot, B, at a right angle, is held fast to the work with a clamp, C. The sliding bar D is pinched at a suitable height, to receive the thrust of the drill E. There are shallow, countersunk holes in the under side of this bar, into any one of which the conical end *a* of the drill-spindle enters. The turning of the nut F with a bit of wire through a small portion of a

revolution, gives the necessary feed to the drill; which is operated with the ratchet lever G. The lever is moved from right to left in the direction of the arrow through a portion of a revolution —about a third or a fourth of a circle, for cutting—the ratchet enclosed in the boss H pulling the drill round to a corresponding amount. In turning the lever back, from left to right, the ratchet click does not operate, but simply slides upon the ratchet teeth. After about three or four of these alternate forward and backward movements, the nut F is tightened again for feed, and the operations repeated.

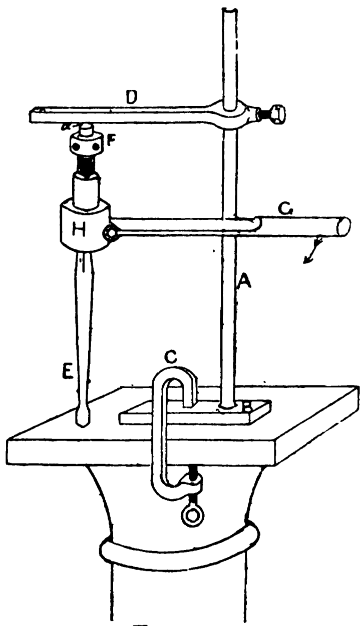


FIG. 203
Drilling Holes with "John Bull."

Sometimes the pillar is rigged up differently. To drill a hole in the edge of a plated casting the pillar would be provided with a foot like that in Fig. 204 for clamping to the plate, and the cross arm and drill arranged for drilling into the edge of the work. Holes are sometimes drilled in boiler shells by fastening the pillar with a chain encircling the boiler, if there are no holes in the shell available for screwing the foot of the John Bull to.

Arboring.—When holes have been drilled, it is customary

to face off so much area around the holes as will be covered with the nuts or washers. When the entire surface of work has been faced this is not necessary; but it is done on all rough castings, or on forged work, unless indeed, this is of a very cheap character. Without it, rough faces are seldom true enough for the nuts and washers to bed evenly upon, one frequent source of inaccuracy being the taper which is given to patterns, causing the washers and nuts to grip only upon one side

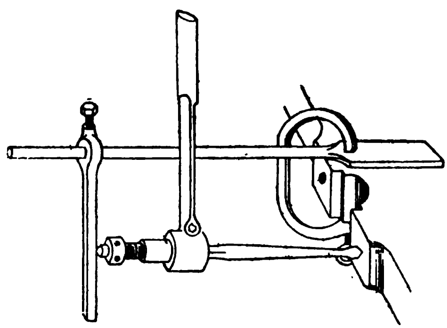


FIG. 204
Drilling Holes with "John Bull."

of their holes, producing a tendency to strip the thread. The operation of facing is termed *arboring*. When it is done in the drilling machine a counterbore is employed; but the fitter at his work-bench, or during the erection of work, does a good deal of arboring to save taking asunder heavy parts, or parts already fixed to the machines. He uses a tool like that shown in Fig. 205. It consists simply of a slotted mandrel, A, like that for boring holes, carrying a facing-cutter, B, held in place with a small wedge, C. The mandrel is inserted through the hole, the face of which has to be arbored, and the cutter is pulled up to its

work by the nuts D. After one or two revolutions of the mandrel and cutter, using a wrench for the purpose, fitted over the square end *a*, the nut is again turned through a small portion of a revolution, and the mandrel rotated once or twice more, the cutter taking off a few fine scrapings each time. The result is that the face is made perfectly true, and at an exact right angle with the hole.

Chipping and planing strips.—A device of very great economical importance in the fitting shop is the employment of chipping or planing strips in place of abutting solid faces, saving the labour of chipping or machining those solid faces. Strips are variously arranged, and a little judgment is required in their arrangement. Whether they are cut and fitted with a chipping chisel, or faced in a machine—in either case the aim is to lessen as much as possible the extent of surface to be reduced, consistently with good fitting and rigidity. A few practical examples will make this clear.

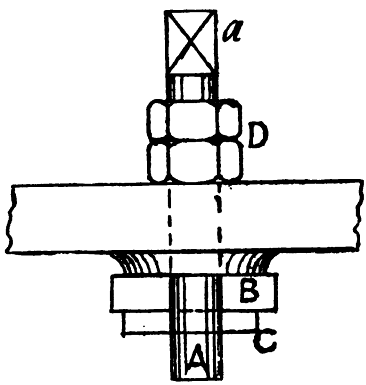


FIG. 205
Arboring.

One of the commonest methods of arranging chipping strips is that shown in Fig. 206, where they are carried all round the face of the foot. This is always the neatest method, because when the foot is bolted in its place, it has the appearance of solid metal all round the edges. But the labour involved in fitting is greater than when the strips are arranged on two sides only, or in three

parallel lines, as in Fig. 208. The latter methods, therefore, are frequently adopted. But when the strips are carried all round, as in Fig. 206, better support is given to the foot than when they are carried along two sides only.

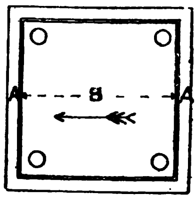


FIG. 206

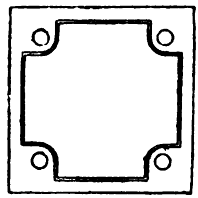


FIG. 207

Chipping Strips.

And when, therefore, the area of the foot is considerable, and strips are not carried all round, it is necessary to increase the number, using three or more, running parallel with each other. But in either case, when these parallel strips are chipped by hand, they might nearly as well, as

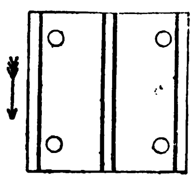


FIG. 208

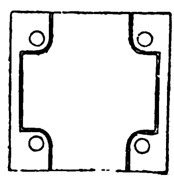


FIG. 209

Chipping Strips.

far as saving labour is concerned, be simply carried round, as shown in Fig. 206, with the advantage of neater appearance. Not so, however, when they are planed on a machine. It is then that time is economized by arranging parallel strips in one direction. For since the work has to be planed at one setting, the tool cuts in one direction only. In the space, therefore, between the longitudinal

strips in Fig. 206, the tool is mostly "cutting wind," as the phrase is—that is, if operating in the direction of the arrow, it cuts the narrow widths A only, and is idle during the length of travel B. For this reason also, when the parallel strips are being machined, the tool is made to cut lengthwise, or in the direction of the arrow in Fig. 208—not crosswise, and after one strip has been planed, the tool-holder is traversed along by hand to commence the next strip. For the same reason of economy, when a large piece of work must necessarily be secured and travelled in a certain position on a planing machine, or when it is advantageous to arrange a large number of similar small pieces in one position, to be planed off all together, then it is often possible to arrange the strips to be cut lengthwise, to suit that position. Very considerable economy in time is often effected in this way. That, for example, would determine in many instances whether the strips should be arranged lengthwise, as in Fig. 210, or crosswise, as in Fig. 211. In many jobs, from the point of view of strength and rigidity, it would not matter in which direction the strips were put.

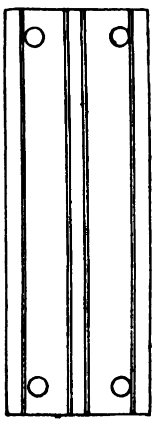


Fig. 210

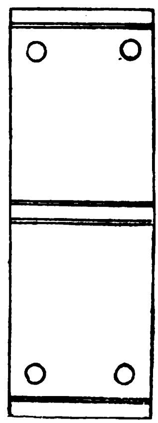


Fig. 211

Chipping Strips.

Another matter in connection with planing strips is, that it is usually desirable that they should either come adjacent to bolt holes, or else should surround them, in

order to afford ample support and rigidity, and to prevent risk of the bolts cracking the foot by undue tension. In these cases the bolt holes should either clear the strips altogether, or be entirely embraced by them. If the holes come partly in the strips, partly within them, they give much trouble, either in coring or in drilling. Examples of good arrangements of holes and strips occur in the figures. In Fig. 206 the holes are in the four corners, just within the strips. In Fig. 207 the strips are made

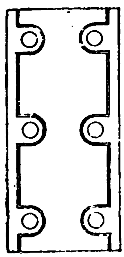


FIG. 212
Chipping Strips encircling Holes.

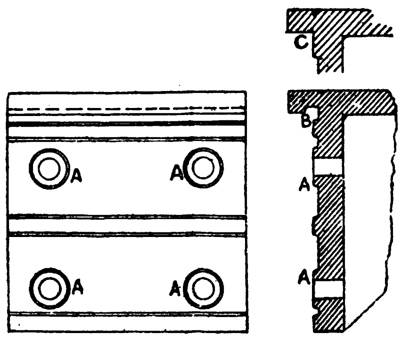


FIG. 213
Planing Strips.

to surround the holes by putting filling-up pieces, or bosses, in the corners. In Fig. 208 the holes come within the strips. In Fig. 209, where two strips only are used, they are extended to surround the holes. The arrangements in Figs. 207 and 209 make the best job; those in Figs. 206 and 208, are, however, quite workmanlike and usual. Fig. 212 is a modification of Fig. 209, adapted to a long, narrow foot. In Fig. 213 circular isolated facings, A, surround the bolt holes. This figure also illustrates another common device in planing strips. The overhanging strip at the top rests on wrought-iron

framing. A space, B, is cored out, to allow the tool to clear the corner, which is much better than having to cut into a keen angle, as at C, formed by the meeting of

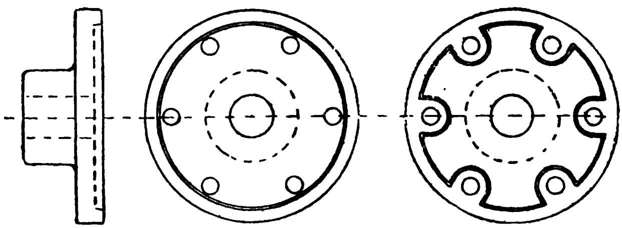


FIG. 214 FIG. 215
Chipping Strips on Circular Faces.

the strips. Figs. 214 and 215 show the strips on a circular boss or plate. In one case, Fig. 214, the bolt holes are not inclosed; in the other, Fig. 215, they are

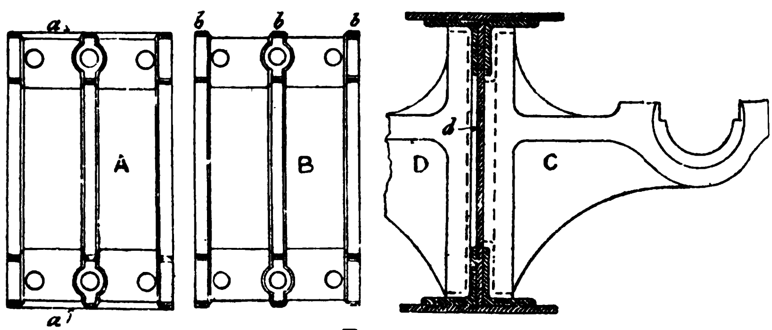


FIG. 216
Chipping Strips on Angle Irons.

Fig. 216 shows, A and B alternatively, how the foot of a bracket or bearing is fitted to built-up girder work. At A the strips *a* run all round, so that when the bracket is fitted, there is an appearance of solidity that is not seen

at B, where the strips do not run along the top and bottom edges; but the fitting takes place only by the *widths* of the strips *b*. One is, however, as good as another in respect of strength. Again, in Fig. 216, the bracket casting C is fitted around the angle irons and upon the face of the web. But on the side D it is shown not carried up against the web, but a packing plate *d* is inserted between the casting D and the web, flush with the inner faces of the angle iron.

The width of chipping strips bears some practical relation to the dimensions of the work, ranging from $\frac{1}{4}$ in. wide to $1\frac{1}{4}$ in. From $\frac{5}{8}$ to $\frac{3}{4}$ in. is the average width, and these are easily chipped.

A great advantage of these strips is the facility which they afford for the adjustment of large castings upon cast iron or upon plated work. This is an advantage quite distinct from that of saving of time effected in reduction of the area which has to be chipped or machined. When a bearing at the end of a long bracket has to be adjusted perfectly in relation to some other portion of a mechanism, a very little material removed from one part of the strips upon the foot will effect a considerable alteration in the centre of the bearing. The longer the distance from the foot to the centre, and the smaller the width of the foot, the greater will be the disproportion between the amount taken off by chipping and the alteration thereby effected in the position of the centre. But to be making adjustments by cutting material from a solid face—taking so much from one edge down to nothing on the edge opposite—would be a dreadfully tedious job.

Chipping strips are sometimes made use of on rough work where there is no intention of planing or of chipping the strips. When castings have large faces which have to

be bolted to cast or wrought iron work, strips are frequently employed merely to obviate the possibility of having to chip or plane lumps and fins off the face. Soft ramming will often cause lumps to gather on the faces of work, an $\frac{1}{8}$ in. or more in the highest portions. Also joints of moulds will overlap and cause a shoulder on the surface, or the loosening of the pattern in the mould will cause the face to come out convex. When these inaccuracies are likely to occur, it is always safer to put strips on. Then, if the casting comes out true, well and good; but if the lumps or lapping joints occur, it does not matter much. Whereas, if there were no strips, the work of going over a large area with chisel and file, or upon the machine, would be a tedious and costly job, representing so much unnecessary and lost work.

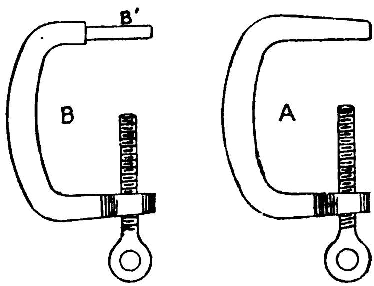


FIG. 217
Cramps.

Cramps of almost all sizes are used by fitters, of the types and general proportions shown in Fig. 217. They are forged in wrought iron or steel. A is that in most request, B being a special form used in cases where there are not two flat surfaces in opposition. Thus, in pinching two plates standing at right angles, united with angle iron or other attachments, the round part B′ would enter into a cored or drilled hole, and offer the necessary resistance to the pressure of the screw.

CHAPTER XII

GEARS, SHAFTING, BELTS AND ROPES

Toothed gears.—The principal advantage possessed by toothed gearing is: that power can be transmitted by it to adjacent shafts which are too close to be driven by belting or ropes, excepting by return methods. Also that it can be transmitted to shafts at right angles, which can only be done with belts or ropes having twisted drives. Although the services of toothed gearing have been lessened in this field, yet there are many drives having the characteristics indicated, for which it still affords the best, and in some instances the only available method.

It is at high speeds chiefly that the objections to toothed gearing becomes greatest. Wheels are noisy, and knock themselves and their bearings to pieces. But the reputation of toothed gearing has suffered largely from the sins of bad design in the past, teeth having been incorrectly designed and badly proportioned, and wheels hung on shafting with bearings of the rigid type. The mortise wheel is invaluable in mill drives in diminishing noise and conducing to smooth running. Even supposing that cut gears should be used generally in mill work, they would not be so good as the wood and iron combination. There is no backlash in these when new, and the elasticity of the wooden teeth absorbs most of the vibration, so that high speeds are practicable as long as the bearings and general fittings remain in alignment, and but little worn.

When shafts run parallel with each other, too close together for a direct belt drive, then there is no alternative but to drive by gearing, or by an indirect belt drive, or by chains. As a general rule, gearing is then the better mode of transmission. In such cases spur wheels are used, made of the relative proportions to transmit the required velocity ratios.

When shafts have to run at right angles with each other, then bevel wheels are employed. Practically the only alternative and rival to this is the rope drive taken off to separate floors. Speaking generally, this is to be preferred, and obtains more favour in modern mills than bevel wheel main drives. But numerous subsidiary details of arrangement occur, in which the rope drive cannot well be utilized, as in transmitting power by short lengths of shafting, and here the great value of the indispensable bevel wheels is seen, by means of which any velocity ratios can be transmitted. Besides this, the bevel wheels are adaptable to driving at many angles other than the right angles, for which very awkward twisted drives with belting or ropes would otherwise be necessary.

Tooth lengths.—There is an important difference in the old and in modern gearing, which tells in favour of the latter and which must be noticed. It relates to proportions of teeth.

During a period covered roughly by the last ten years much improvement in tooth forms has been apparent. The principal difference lies in tooth lengths, which have been shortened in the best practice. Changes of this kind cause inconvenience in the mating of new wheels to old ones, and should not be adopted without substantial reasons. The fact that tooth lengths have exceeded their best limits has been suggested long ago, but little improve-

ment was noticeable until Mr. Michael Longridge made a special study of the subject, and demonstrated that a large number of tooth fractures in mill wheels were traceable to their long teeth. He advised, in consequence, a length of tooth equal to about one-half the pitch.

This seems very short to those accustomed to the old teeth, the length of which measured generally twelve-fifteenths of the pitch, and some certainly exceeded that length. But that the old were wrong, and that the new proportion is correct is clear from the following considerations. (Compare with Fig. 218.)

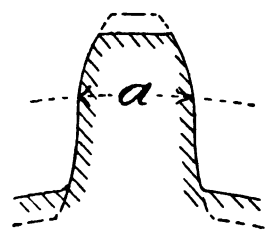


FIG. 218
Tooth Lengths.

The length of a tooth is merely a matter of convenience —that is, it has no relation to the radius or leverage of the wheel. The strength of a tooth is governed by the width or thickness *a*, which is determined by the pitch. From one point of view, the shorter a tooth is made the better, since it would be really better to drive by frictional contact than by teeth at all. The shorter the teeth are the less is there of sliding action, and the less trouble is experienced in consequence of the extremes of thickness at point and root. These are points in favour of the short tooth, shown by full lines in Fig. 218.

On the other side, little can be said in favour of the long tooth indicated by the dotted line in Fig. 218, except its antiquity and an increased wearing surface. It is clearly a relic of the times when exact dimensions in the sizes of wheels and the centring of shafts were difficult of attainment, and when the length of tooth was made to a

considerable extent the means of adjustment, being put closer into, or farther out of gear to suit the shafts, or to allow for wear. Another point was, perhaps, that a long tooth pleased the eye better than a shorter one. It looked noble, shapely, and capable of doing some work. As a cantilever, however, the longer a tooth is, the weaker it is.

With short teeth these evils are reduced to a minimum. The limit to this shortening seems to be only that at which wheels will remain in mutual gear without possibility of jumping and overriding. This opens up the question of the degree of accuracy attainable in mill work, and that of good design. It presupposes stiff shafting, good bearings and due provision for taking-up wear.

Adjustments.—The adjustment of gearing is an important matter, involving two main points: the truth of the shafts, and the proper working depth of the teeth. The methods by which the first is secured are described in Chap. XI. Here we consider the second only. In all cycloidal gears there is only one precise position of the teeth in mutual engagement, at which they will work in proper rolling and sliding contact. At any other position the path of contact will not pass through the line of centres which joins the two wheels. In involute teeth there is no such hard-and-fast position. The difficulties of gearing up cycloidal wheels truly are considerable. If one pair of wheels only is concerned, and their centres are adjustable, there is little trouble; but when there is single and double gear, and shaft centres are fixed rigidly by templet, as in repetitive work, it often happens that some pairs of wheels have to be set too slightly, and others too deeply into gear. Moreover, since many gears are cast, and there is taper on patterns, and many patterns have seen long service, and moulders differ in their methods of ramming—some ramming hard,

and some soft—with the result that the teeth come out more or less lumpy; and also, since some men rap patterns more than others, and some mixtures of metal shrink more than others, the result is a want of uniformity in gears nominally alike. In machine-moulded wheels the same evils occur, but in a lesser degree. Their teeth are more accurate, but their diameters will vary, the radius being set with a strip given to the moulder. Hence it is common in sets of work to find that wheels made from the same pattern, or toothed block, gear nicely in one case, and in another work too freely or too tightly, and even that abominable eyesore to an engineer—teeth turned and chipped to make them engage freely—has sometimes to be resorted to. In steel gears, which are used to a considerable extent, an evil of another kind occurs, and one which is apparently unavoidable. Steel wheels of moderate and of large diameter, cast with arms, always shrink considerably more across the diameter that corresponds with the length of the arms, than across the diameter between the arms. On wheels of 4 or 5 ft. in diameter, the difference will frequently amount to $\frac{1}{4}$ in. or $\frac{5}{16}$ in. Moreover, the faces of steel wheels are frequently as much as $\frac{1}{4}$ in. winding. This involves skimming up the points of the teeth and the faces in the lathe.

Involute gears.—In the involute system we must dismiss ideas associated with the cycloidal gears from the mind. In the latter the pitch circles are actual rolling surfaces, the positions of which cannot change. In involute gears there are no actual pitch circles in the same sense. We speak of them, in a different sense from those of cycloidal teeth; they are circles corresponding with velocity ratios, but not the base circles upon which the tooth curves are rolled. And thus it is that the centres of involutes can be

moved in relation to each other without interfering with correct action—a few special cases of small pinions alone excepted—while the movement of the centres of wheels with cycloidal teeth changes the correct relations of the tooth curves.

The only important circles, therefore, in involute wheels are the base circles from which the involute curves spring. No mutual action takes place between the teeth below the base circles. Since the base lines in involute wheels limit the line of action of the teeth, there is no advantage gained by increasing the depth of tooth beyond the amount actually required for clearance. The working part is wholly above these lines, so that strictly the action is that between faces and no flanks. The position of the base line is determined by the angle of the line of action, that in the wheels being a curve tangential thereto.

These are some of the difficulties which are met with in gearing up wheels, and obtaining their correct centres. And for these reasons it will not do to take the reputed pitch diameters of the wheels from the drawing, and mark the bearing centres from those. The centres should be taken from the wheels themselves when put in actual gear.

Centres.—Taking spur wheels first, a very common practice is to lay strips of wood or metal, *a a a a*, in the roots of one wheel, Fig. 219, A, and roll round the wheel B, which has to gear with it, so that its points come into contact with the strips *a a a a*. The thickness of the strips *a* is equal to the amount of bottom clearance given to the wheels; hence, when a tooth in the upper wheel is in the centre of a couple of teeth on the lower wheel, its point will be in contact with the thickness strip. Then, if the wheels run too freely, thinner strips are inserted; if too tightly, thicker ones. When the proper

amount of working fit is found, then the centres of the wheels in that position are taken with trammels, and the centres of the bearings marked off therefrom. Although

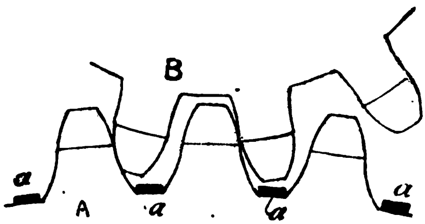


FIG. 219
Adjustment of Bottom Clearance.

this plan secures the end desired, it is, after all, but a clumsy rule-of-thumb method. The proper way is to obtain centres, to strike the actual pitch circles upon

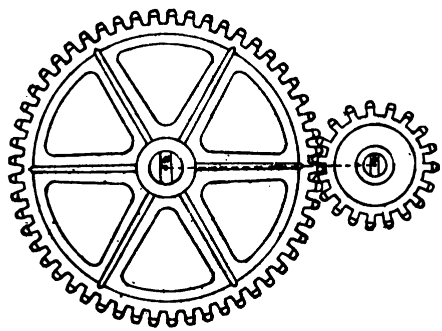


FIG. 220
Taking Centres of Wheels.

the wheels, and placing them in contact in the line which joins the centres, Fig. 220, then trammel off the wheel centres *a* *b*. In order to do this, the marker-off should have a list, showing the precise position of the pitch line in relation to point and root for wheels of all pitches.

This is easily done when the system of wheels used in a firm is uniform. But in too many cases there is no such uniformity, and then all that can be done is to give the general proportions for any given pitch, and leave the marker-off to make the best approximation to those proportions, with teeth of varying lengths. Sometimes the pitch circles, if struck deeply in the pattern, will show sufficiently clear in the casting to enable the marker-off to set the wheels by them. But whether thus visible, or struck, the

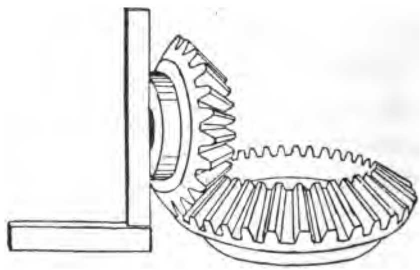


FIG. 221
Setting Bevel Wheels at Right Angles.

difficulty of the wheels not being circular, and especially in steel gearing, arises. Then the wheels will work freely in one position, but tightly in another. It is therefore necessary to try them round in several different positions, and average the results. Similarly, when obtaining the centres of wheels for double gears—that is, when it is necessary to gear two pairs of wheels having different ratios upon the same shafts—one pair may have to be put rather tightly, and one pair rather easily in gear.

Further, there is more or less of taper on teeth moulded from patterns, and it is a good plan, when practicable, to reverse the taper when keying the wheels upon their shafts. Also, if patterns are very bad, or castings lumpy,

it will be necessary to use the chisel and file in dressing off the inequalities that interfere with free movement. But this practice should never be resorted to unless absolutely necessary, because there is more durability of wear in the outer skin of a casting than beneath the skin.

In the case of bevel wheels there is not only the proper depth of gearing the teeth to be kept in mind, but also the proper angles of the shafts. But since all wheels have their bosses faced, these afford a test of truth. Thus, a pair of bevel wheels would be set as shown Fig. 221, to try the gearing of the teeth; and the teeth should gear properly when the boss faces are at right angles with each other. Any other angles than right angles for gearing would be tested with a bevel, properly set.

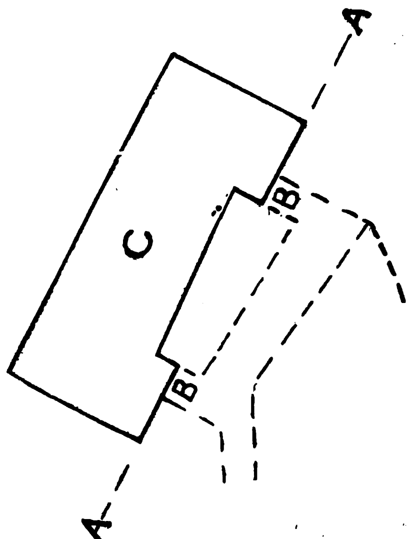


FIG. 222
Templet for Half-shroudings.

Shroudings and bosses.—When turning half-shrouding of wheels, it is not enough to turn down the shroudings until the wheels run freely. One may easily get $\frac{1}{8}$ in. out of truth in this way, and so cause trouble. The wheels should properly be struck out in section, and the correct pitch circles drawn, and templets made therefrom to turn

the shrouds by. Fig. 222 shows such a templet, C, its relation to the wheel rim being apparent by the lines dotted; A A being the periphery of the pitch cone, with which the shrouds or collars, B, have to correspond.

The bosses of bevel wheels are faced off, and their dimensions taken from the centres of the wheels with which they gear, and the dimensions are always given in this way on workshop drawings. Thus, in Fig. 223, the

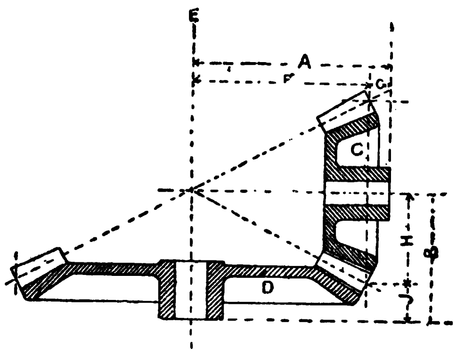


FIG. 223
Taking Measurement for Boss Facings.

distance A equals the distance of the boss of the pinion C from the centre E of the wheel D. Half the pitch diameter of D, equal to the radius F in the figure, is therefore subtracted from A, and the difference G equals the distance by which the boss of C must stand above its pitch line. Similarly, the radius H of the pitch diameter of C is taken from B, and the difference J equals the distance by which the boss of D must stand above its pitch line.

Erecting shafting.—There are several ways of erecting shafting. One is, to set out the position of the intended

shafting on the underside of the overhead beams. A chalk line is snapped, making a mark over the intended position of the shaft. Many have been set in this manner, but it has the disadvantage that it becomes troublesome when several shafts have to be located at right angles. Having the lines marked, the positions of the bearings in the vertical plane are obtained by a plumb line. The device of a long parallel straight-edge and level is adopted to secure alignment in the vertical direction, while for testing that in a lateral direction a straining cord is used. The latter can be pulled taut along the edges of the open brasses, or at a little distance away therefrom, measurement being taken thence to the bearings, or to the shaft if the latter is in place.

When machines already occupy the floor area, the bearings must be put up thus from above. But the best plan when the floor space is available, as in putting in a plant in a new shop, is to lay down the positions of the shafts on the floor. Their centre lines are marked on the floor with a straining cord. Then this line is crossed at intervals with blocks of wood, which have to be all levelled exactly by means of a level and parallel straight-edge, the straight-edge being traversed from adjacent pairs of blocks, and shavings removed where necessary, until all are level: the result is a basis independent of the inequalities of the floor, from which basis the shaft can be levelled truly. Measurement is taken with a staff directly from the block in the first place to the bottom of the bearings, and afterwards to the underside of the shafting. Lateral adjustment, as before, is obtained with a straining line.

When bearings are fixed by lines laid down on the floor with a strained chalk line snapped carefully, then, as the chalk marks will become obliterated, the end locations are

fixed by driving in small nails. The positions of all shafts should be lined, and marked thus.

To strike lines at right angles with each other, a square is inadmissible because too short to give correct results. The rule "three, four, five," for obtaining a triangle is better; strips of wood, a long rule, or a trammel can be used for the purpose. Lay out 3 ft. on the base line, Fig. 224, from the point where one shaft is to intersect the other. Mark off a radius of 4 ft. from the starting point on the base, and 5 ft. radius from the 3 ft. point, to cut the 4 ft. radius. The point of intersection will, when connected to the point of intersection of the shafts, be at right angles with the base line.

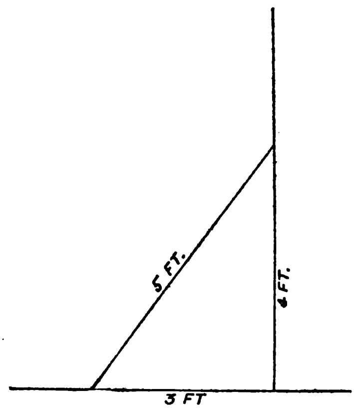


FIG. 224
Marking Lines at Right Angles.

Either of the geometrical methods of obtaining lines at right angles will also be suitable for adoption, provided radii of ample length are taken to eliminate error.

Lines at right angles on a floor to large dimensions may be drawn by a strip of wood having two nails in it. Fig. 225 shows the method. To bisect the line A B, set the rod alternately in A and B, and scribe arcs of circles on opposite sides of the line A B, as shown. A line drawn through the intersections will be square with A B.

Having the centre lines of shafting laid down on the

floor, set out also the positions of the bearings, and drive a nail in at the positions which correspond with the centre of each bearing. Plumb from these to the beams, and mark a centre on the latter exactly over the centre of each bearing. Make a templet to suit the bearings to be used, having a centre hole in it, and the bolt holes drilled in the same positions as those in the bearing feet. Lay

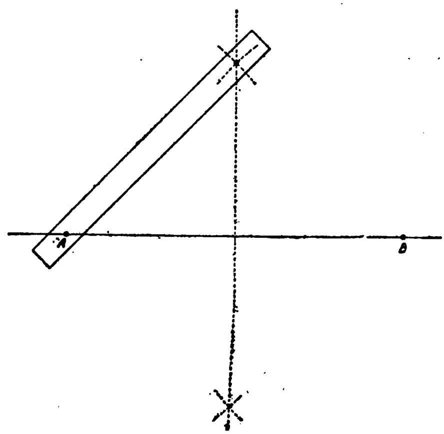


FIG. 225
Marking Lines at Right Angles.

the templet under the beams with its centre hole over the centre plumbed on the beams, and mark off, and bore the bolt holes. By these the bearings can be bolted in place.

The shafting will now be laid in the bearings, in readiness for final adjustments. The first setting will be that sideways; this will be set with a plumb line over the floor. The line may either be looped over the shaft—in which case the centre of the shaft on the floor will be plumbed—or it may be set by one edge of the shaft, and

then a line will have to be snapped on the floor for guidance at a distance of half a shaft diameter away from the centre line.

The vertical adjustment then follows. A couple of rods will be taken and notched to fit over the shafting, and to support a parallel straight-edge A below, Fig. 226. A start will be made from an end bearing, and each length corrected in succession by means of a level placed on the straight-edge.

The risk of working with a spirit level is that few shop

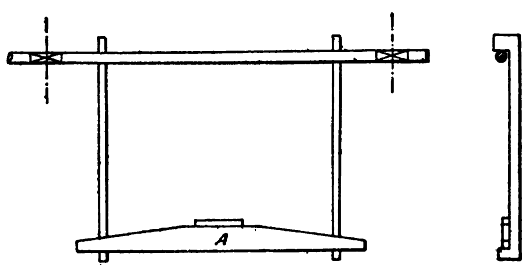


FIG. 226
Horizontal Adjustment of Shafting.

levels are true. Sometimes a surveyor's level is used, and sights taken—a most accurate method.

When a spirit level is used, it should first of all be corrected by planing or filing the bottom if it has become worn by use. Then when employed in service it should be reversed, end for end, for every sight. Some set the level directly on the shaft; but this is not to be relied on unless the shafts are exceptionally true. If used in this way, the level should be laid upon a long parallel straight-edge laid upon the shaft, by which device local inequalities will be merged in an average result. Levels, too, are often attached permanently to a long parallel strip, carefully

corrected, which amounts to the same thing as interposing a temporary strip between the level and the work.

To lay down parallel shafts in adjacent shops, in which a dividing wall interferes with ordinary methods of measurement, a doorway may be utilized for the laying down of a line at right angles with the shaft in one room, and this line can then be made a base for obtaining another at right angles with that, and parallel with the one in the other shop. Even though geometrical methods are used, and the measurement made as large as possible much care is necessary to insure complete parallelism by this method.

One way of erecting shafting is to locate the bearings from one end, working mainly in reference to a strained line, or to a wall or beams, but adjusting each separate bearing from that adjacent. Thus, the general positions of the bearings being indicated, an end one is bolted down, with the cap and top brass removed. The next one is set by a parallel straight-edge laid in the hollow of its bottom brass, and extending to the same position in the first one. Lateral adjustment is effected by a straining line pulled taut along one edge of the brasses.

Wall brackets.—To fit wall brackets, proceed as follows: Mark the vertical lines Fig. 227, A, on the wall, which correspond with the centres of the brackets. These will be obtained with a plumb line. The line will be chalked, and, when it is at rest, plumb—the top and bottom will be held firmly, and the line snapped, transferring the chalk to the wall—then chalk or scribe a line corresponding with the exact centre of the shaft, using a long straight-edge and spirit level for the purpose. Prepare a templet of wood or sheet metal, having holes bored in it to correspond with the holes in the foot of the bracket, and

either with a top edge or a centre line, coincident with the centre of the shafting. A vertical centre line will be scribed and carried over the ends. The templet is laid against the wall, is set by the centre lines, and the bolt holes scribed off on the wall, and bored through.

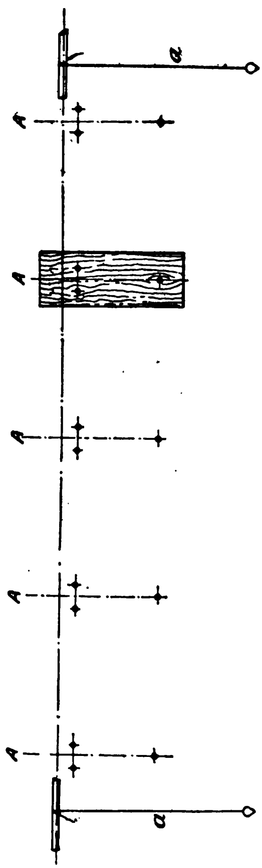


FIG. 227
Fitting Wall Brackets.

The next stage is bolting up the brackets. These may be all fastened before the shaft bearings are put in place, levelling and checking by the planed faces which receive the feet of the bearings. The latter are presumably bored and faced truly in the feet, and all of the same height. The first bracket is fixed by its holes and bolts, then the one adjacent is adjusted and fixed in reference to the first, using a parallel strip and spirit level; thence adjustment is made to the third, and so on along the line.

The bearings can be now bolted in place, and the shaft inserted. Before finally inserting the wedge pieces at the ends of the bearing feet within the joggles, the truth of the shaft will be checked. The horizontal accuracy will hardly be departed from at all; but a spirit level can be tried upon it. The principal test, however, is that in the lateral direction. This is checked

by dropping plumb lines over the shaft at the extreme ends, *a*, and at places intermediate, and sighting along them. Adjustment of the bearings by means of the end joggle packings can be effected when all the bearings are in line.

Parallel lines of shafting are laid out either by marking them with chalk lines on the ground, and plumbing by them, or by working from one shaft already fixed, using a gauge which measures the exact distance between the shafts; or if the shafts are parallel but not in line, a cord may be extended from one already fixed, and measurement taken from the cord to the shaft adjacent.

Pulleys are set in line by means of a cord strained from the edges of the fellow one. In case the pulleys should be badly hung, which, of course, should not be the case, the shaft may be turned a quarter round and tried again. There are two excellent tests of the mutual fitting of a shaft and its bearings. The first is the turning of the shaft by hand, when the good fitting or otherwise is indicated by the degree of freedom with which it can be revolved completely and in different positions of rotation. The other is seen in the results of lubrication. If a bearing is being cut away by its shaft, the waste lubricant is coloured and thickened more or less deeply by the abraded metal or alloy. If it is not, the lubricant remains clear for an indefinite time, so clear that it can be used repeatedly.

Swivel bearings.—The erection of shafting has been much simplified and cheapened by the use of swivel bearings. When bearings can be adjusted in place, there is less necessity for the care in setting the pedestal bracket, hangers, etc., just described. It is extremely difficult and tedious to fix up these to beams, walls, and pillars by the aid afforded by straining lines, straight-edges,

levels and strips. These are all open to errors, slight in themselves, and relatively to the nature of the aids and appliances used, but of considerable magnitude in relation to the linear truth of shafting. It must be clear to any one that there is a vast difference between fixing a bearing true by its foot to a beam, wall, or pillar with bolts, and adjusting a swivelling bearing in its foot, or surrounding framing. Apart from the awkward character of the work in many locations, it is not possible to obtain so great exactitude in the first case as in the second. A number of little liabilities to error creep in, all more or less cumulative. Even the final tightening-up of bolts will draw the work out of truth to an extent greater than is really permissible in the correct alignment of shafts. So that men will not infrequently spend as much time in making minute adjustments, without anything to show for their work, as would suffice to erect and finish a line of adjustable bearings. And then there is the possibility that similar adjustments will have to be performed again within a year or two.

In erecting rigid bearings adjustments have to be made in vertical and horizontal directions, and it is the combination of these which wastes so much trouble and time. When one is got right, the other is often found to be wrong, and the work has to be gone over again.

One method of erecting shafting takes advantage of the use of a water trough, laid down in place of the levelled blocks just now alluded to. The Webster Manufacturing Co., of Chicago, have improved on this by the employment of a hydrostatic level. It consists of two tubes set vertically on feet, connected with a length of hose, and fitted with stopcocks. The tubes are divided into inches and parts of the inch, and will indicate to $3\frac{1}{2}$ in

variation in height. Within that limit the level of the water in the tubes will give truly horizontal positions anywhere up to 25 ft. apart.

Belting.—Few, if any, details of millwright's work have caused more persistent trouble than belting. Rules, apart from experience, are of little aid in practice. The whole subject bristles with difficulties. Differences in length of drive, in proportion between thickness and width of belt, speed of driving, size of pulleys, and of belt tension complicate matters, and increase or lessen power cost very materially. Hence it follows that while some firms have incessant trouble with their belting, others experience immunity therefrom. Yet there is no chance work at all about this, but effect follows surely after cause, and common sense carries one farther than formulæ.

Any old engineer knows that belting is often a source of great trouble, that it is very expensive, and deserves much more attention than it receives in many shops. The spectacle of weak belts, patched belts, wavy, uneven belts, slipping and screeching belts, belts too short, belts too long, belts too tight, belts too loose, belts badly laced, and much more is witnessed in many shops.

Belting is made of leather of various grades, of canvas, of camel hair, llama hair, cotton, indiarubber, and gutta-percha.

It is as well to say at once that no class of belting whatever is equally applicable, and suitable to all the conditions which arise. So that before the most suitable agency for driving can be determined in any case, the conditions must be known. A matter which has to be considered in some situations is the ability to stand great heat, steam, frequent changes of temperature, moisture, and so on. A belt of good quality for some purposes will often be

unsuitable for use because of the conditions imposed by situation.

But for the general purposes of transmission indoors, at ordinary temperatures, for the driving of machines in general, there is "nothing like leather," after all, provided it be good, honest leather. A good belt will endure three or four times as long as an inferior one. It is not meant to imply by any means that the woven beltings are not good. But there is a durability, a rigidity about the best leather which renders it better qualified for hard, severe duty than anything beside.

The reputation of belts has suffered in consequence of the employment of inferior leather and of ignorance of conditions which conduce to long life. If firms have cheap belts, they get the inferior parts of the hide, the flanks and offal, instead of the butt; such belting is dear at the best. It has a short life; is always stretching and giving trouble, and does not last a fourth as long as the best. A good leather belt, well cared for, will last the average man's working lifetime in the shops, and cannot be beaten by any other material.

Lengths of belting.—Methods of calculations based on trigonometry are given in text books for obtaining the lengths of belting. In the shops the length is always taken with a cord laid round over the pulleys—a safe and simple way. After the length is obtained thus, a slight allowance is made for tightening. That is done, because, if the belt were laced up to the exact length given by the cord, it would fit too easily on the pulleys, and would have to be relaxed almost immediately.

The allowance given varies with the character of the belt. It should be greater in a new than in an old one, in which most of the stretch has been taken out.

Generally, before new leather belts are used they are stretched a little by hanging them from a beam and loading them with half-hundred weights, or by using a *belt stretcher*.

The allowance given when lacing depends on the length of drive. From $\frac{1}{2}$ in. to 1 in. in 10 ft. less than the measured length is a fair allowance, depending on the conditions just named. In any case the tension will soon fall by reason of some stretch taking place.

To measure the length of belting when in the roll:—To the outer diameter of the coil in inches, add the inner diameter, also in inches; multiply this sum by the number of coils in the roll, and by 0·1309. The product will give the length of the belt in feet.

To settle a minimum distance between pulleys is not always easy, because circumstances often do that. Reddaway & Co. fix it at one and a quarter times the sum of the diameters of the driving and the driven pulleys. If pulleys are nearly equal in diameter, they can be brought closer; if much disparity in size exist they should be set rather farther apart; but an excessively long drive causes the belts to sag, and flap, by their great weight.

When possible, pulleys are best proportioned to give belt speeds not exceeding the maximum limits of from 3000 ft. to 4000 ft. a minute. Reddaway's rule is:—For 3500 ft. per minute, the number 13,400 ft. divided by the number of revolutions per minute gives the diameter of the pulley in inches. The same number divided by the diameter of the pulley in inches gives the number of revolutions per minute, at 3500 ft. belt speed.

Horse power.—Horse power of belting as given in tables is very uncertain, because so much depends upon conditions. Tensile strength, speed, grip on the pulleys, which

is dependent on width and arc of contact; freedom from slip or otherwise, all affect results, so that to assume that a given belt will transmit an exact quantity of horse power under all conditions, is to expect too much. Allowances have to be made, and judgment exercised.

A useful and safe rule is to allow 50 lb. working strain for every inch of breadth in a single belt, and 80 lb. in a double one.

The driving of pulleys at various angles with twisted belts is one of the curious feats of engineering. One would think such belts must run off. So they do in most instances, if the direction of revolution is reversed. But if the simple rule is remembered, that the edges of the driving and the driven pulley are kept in the same plane, then the others can come as they will.

Of the numerous kinds of belting made of canvas, cotton, hair, and cementing materials, their principal advantages lie in drives in the open air, in hot rooms, and places where they are exposed to steam and water. The frequent objection to them is that the edges fray out. But this is got over in some instances by the use of protective edgings. The Reddaway, the Gandy, the Dick's, and other beltings are well and favourably known, and are used extensively. Another point in favour of these, besides their ability to stand heat and moisture without alteration in length, and without being spoiled, is that they stretch less than leather, that they are stronger, and that they slip and creep less.

Reddaway & Co., of Manchester, have put down a large number of heavy drives in mills with their camel-hair belting. In an ironworks at Warrington, a compound drive of three belts, each 16 in. wide, was used to operate three sets of ingot rolls from one driving wheel. Large

numbers of the Lancashire cotton mills use these belts. Thinner camel belts will perform the same work as those of leather—a $\frac{5}{16}$ in. belt driving as well as a $\frac{1}{2}$ in. one of leather, with the numerous advantages in regard to diminution of stress and ease of movement that follow.

Pulleys.—Rounding or *crowning* the faces of pulleys keeps the belts well about the centre. Pulleys running on vertical shafts should have more *crowning* than those on horizontal ones. From $\frac{1}{16}$ in. to $\frac{3}{32}$ in. is enough for high-speed pulleys of about 6 in. in width—about $\frac{3}{16}$ in. per foot of width. Those on vertical shafts may have double this. There is no advantage, but rather the reverse in increasing this amount. Fast-and-loose pulleys should not be rounded, but left quite flat.

An excessive amount of convexity has often been given to pulleys, with the idea of keeping the belt from slipping off. This is now known to be a mistake. It too often was a consequence of the bad fitting of shafting, bearings, and pulleys. If these are set out of line, the belts will run off, in spite of crowning. Actually the slightest amount of convexity is better than a deal. Much rounding means that the belt, if only moderately thick, does not bear nearly across its entire width; and, if a double belt, it will probably not bear so much as one half, and its frictional grip, on which so much depends, is thereby diminished.

The evil is increased with increase in speed, because the effect of centrifugal force comes into force, throwing the belt off the pulley, to which it ought to adhere closely.

The edges of belts become frayed when they run against flanges or against the forks of striking gear. This cannot be avoided—the only thing is to take the capability of a given quality of belt to resist the action as a point in its

favour. Belt forks must be polished, and large belts must be shifted by rollers instead of by plain forks.

Rope driving.—This has advantages in many respects over leather belting. For some purposes it is admirable, but not for every kind of service. Though ropes are cheaper than belts, their pulleys are much more costly. Then there is the difficulty of getting every rope to do its proper share of the work, which has resulted in the use of tightening pulleys, an awkward arrangement when many ropes are engaged in driving. Nevertheless, rope transmission has many advantages in the case of long drives, drives of great power, and twisted drives.

The advantages which ropes possess over belting are not, speaking in a general way, great; but under certain conditions they are decided. They are much better for twisted drives. We know how awkwardly half-crossed belting drives, and how the bevelled belting has been designed to obviate this difficulty. Ropes fulfil this function more efficiently. Again, in very wide main-driving belts there is trouble due to insufficient contact with the pulleys. Using ropes, the contact of every rope can be insured. Another point is, that the tightening up of a wide belt involves much loss of time, while a single rope can be removed, and respliced, while those remaining will continue to drive.

The great value of ropes for twisted drives is on a par with their utility in the transmission of power from the main shaft of the prime mover to distinct lengths of shafting, driving machinery on separate floors. Belting is ill-suited for this service, because the conditions are unfavourable, the reasons of which are apparent from a consideration of the limitations to belt-driving which have been already stated. In fact, belt driving is so inefficient

under such conditions that toothed gearing has been largely used instead. But spur and bevel gears and heavy shafts are not ideal forms of transmission. They are heavy, and generally intolerably noisy if employed to any great extent. As the lesser evil, they have been often preferred to belting. But with the introduction of rope driving much of this gearing has been taken out, and with advantage.

The advantage of the driving of shafts at different angles by means of ropes somewhat resembles their driving by the wedge-shaped leather link belting. Both are highly flexible, and each unit of width takes its fair share of the work. The single ropes are equivalent to a belt cut up into several strips, each lying closely to its work, which a solid wide leather belt cannot do when the drive is not parallel.

When ropes are properly made, and used under suitable conditions, there is little, if anything, to choose between the materials of which they are made. These conditions are, however, of so great importance that they cause, in extreme cases, a difference of between a few months, and six, eight, or ten years in the life of the rope.

A rope differs from leather or chain in this: that, though, like those, it is subject to direct tension, the fibres, yarns, and strands are twisted. The amount of twist permissible has been settled by experience. But in any new rope, some amount of stretch results, which has to be taken up by resplicing two or three times, after which it stretches no more. In manufacture, the yarns, the strands, and the completed rope are successively twisted in opposite directions, in order to neutralize the twists as far as possible. The strain on a rope tends to untwist the strands in one direction, and yarns in the other direction, until the two

are approximately balanced. Ropes are made of three or four strands; some prefer one, some the other. A four-strand rope must have a heart, or core, a three-strand none. A four-strand has a section more nearly circular than the three.

It is clear that a rope is, in two respects, more unfavourably constructed than a belt to endure bending over pulleys. In the first place, its thickness is much greater; in the second, its fibres are more delicate. The practical issue is that the pulleys for rope must be much larger than those used for leather belting, and that their grooves must be smooth and polished to prevent fraying of the delicate rope fibres. Therefore, both internal and external friction have to be minimized.

The fibres of which the rope is built up rub over one another within the rope, tending to break up its structure and reduce it to powder. This is the evil which has given most trouble to rope users. To prevent or diminish the internal friction of the fibres of the rope, which on small pulleys is rapidly destructive to the fibres, is the reason why the pulleys must be as large as possible. There are minimum diameters which are fixed by experience, but it is better to exceed these when possible. Besides this, manufacturers lubricate the ropes when in process of manufacture. The C. W. Hunt Co., of New York, employ plumbago mixed with tallow. This renders the rope also partially waterproof, and, after a little wear, it becomes permeated and coated externally, and hardened by the lubricant. In addition to this, it is well to apply a preparation to the outside of the rope from time to time, especially when it is exposed to weather.

An approximate rule is, that a pulley should not

measure less than thirty times the diameter of its rope. Mr. Coombe gives the following sizes as agreeing well with practice—

$1\frac{1}{4}$ in.	diam.	rope,	3 ft.	diam.	pulley,	ratio	1	to 28·8
$1\frac{1}{2}$ in.	„	„	4 ft.	„	„	„	1	„ 32·0
$1\frac{3}{4}$ in.	„	„	5 ft.	„	„	„	1	„ 34·3
2 in.	„	„	6 ft.	„	„	„	1	„ 36·0

When the size of a pulley must be reduced much below proper proportions, then an alternative is to reduce the diameter of the ropes, and to increase the numbers.

Another important point in rope driving is the speed. This ranges most economically at between 3000 ft. and 5000 ft. per minute, and experiment has demonstrated that nothing is to be gained by going beyond 5000 ft., because the centrifugal force increases more rapidly than the additional power gained, and so reduces the latter.

The total stress on the rope is the same at all speeds. With a given velocity, the *weight* of rope required for transmitting a given horse power is the same, no matter what size rope is adopted. The smaller rope will require more parts, but the gross weight will be the same.

Another and most important point is the stress on the rope. About 7000 lb. is the ultimate strength of a rope 1 in. in diameter; but the working strain should not be more than 200 lb., giving the enormous margin of 35 times. Actually it is less than this, because the strength of the splice is less than that of the solid rope; but the working stress may be taken here as being from $\frac{1}{20}$th to $\frac{1}{25}$th the strength of the joint. This is an enormous margin; but experience of short-lived ropes has demonstrated its necessity. The question is not so much one of static strength as of dynamic working—conditions which cannot

be calculated, but which are found to produce rapid wear.

If a rope is overstrained, the result is seen in the strands becoming loose, due to the partial untwisting of the rope. A rope may wear badly on the outside, even though the pulleys are of ample size, due to the roughness of the pulley grooves, or to their running out of truth, or to adjacent ropes chafing against each other, caused by the bad fitting of pulleys, or too fine pitch of the grooves, or too much sag.

In rope driving there is a large amount of sag to be allowed for. If a rope is pulled up too tightly, it will not last nearly so long as when slack. The limit to sag and slackness is that at which the rope begins to slip. The sag on the driving side is taken as a constant for all speeds, because the tension should be always the same. But the sag on the slack side varies with speed, increasing as speed diminishes.

The splice of a rope is its weakest part, and generally goes first. It must be long, measuring not *less* than from 6 ft. to 12 ft. It must be so made that the diameter at that part shall not be sensibly larger than the diameter elsewhere. The C. W. Hunt Co. give the following table for the length of splices—

Diam. of rope.	Length to allow for splicing.
$\frac{3}{4}$ in.	9 ft.
$\frac{7}{8}$ in.	10 ft.
1 in.	12 ft.
$1\frac{1}{4}$ in.	14 ft.
$1\frac{1}{2}$ in.	16 ft.
$1\frac{3}{4}$ in.	18 ft.
2 in.	20 ft.

This firm insert a coupling in their ropes by which the resplicing under ordinary conditions is avoided. The coupling is fitted to the rope ends, and permits of the rope being shortened by twisting it. It is of aluminium bronze, to reduce weight, and being smaller than the rope, is not open to the objection of striking the pulley grooves. A minor advantage of this is that twisting the rope slightly enlarges it, so compensating for wear.

The most favourable conditions for the life of a rope are, after those already named, those in which it always bends in one direction, and in which the pulleys are situated a good distance apart. To return a rope round binder pulleys or round tension pulleys shortens its life by about one-fourth. This is clear, since bending a piece of material in opposite directions alternately stresses it more severely than bending it and straightening it alternately in one direction only. The farther the sheaves are apart also, the less is the rope strained, because its fibres are bent less frequently; therefore, as with leather, so with ropes, the most favourable and economical method of driving is that in which the pulleys are a reasonable distance apart and the ropes horizontal, with the bottom part of the rope driving. Ropes perform best when the sag on both sides approximates to fixed dimensions, which are understood in practice. On long drives the sag amounts to several feet.

There are two ways of using ropes. In one, termed the "multiple" system, a number of separate and independent ropes are employed side by side, each running in its separate groove; in the other, the "tension" system, a single rope is passed round a succession of grooves. The latter is the American system. But though now known as the American, it really originated at Belfast in 1878. The device, however, has not been adopted much here, and in

cases where it has been fitted in England, it has been done chiefly, if not wholly, by American firms.

In the tension system, the rope is reeved over the first groove of the first sheave to the first groove of the second sheave, back to the second groove of the first sheave, and so on until the grooves are all occupied. Thence the rope passes from the last groove of the first sheave to and over

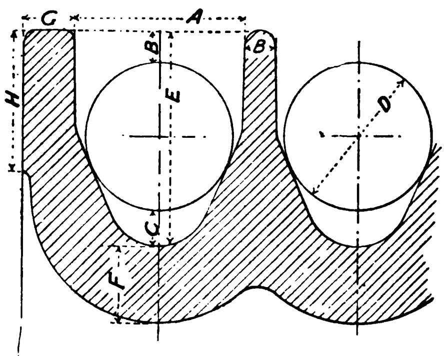


FIG. 228
English Pattern Grooves.

the tension sheave. The rope is endless, with but one splice, and the tension allowance for stretch varies with the number of sheaves and their distance apart, and the nature of the atmospheric changes which are likely to occur ; ropes exposed to weather requiring a greater range than those which are not. Lengths of from 15 ft. to 30 ft., or 40 ft. in extreme cases, are, therefore, required with varying conditions.

Not much diversity of opinion exists in reference to the angles of the sides of the pulley grooves: 45° was settled many years ago at Belfast. The principal variations are illustrated here.

Fig. 228 illustrates common English practice, and the formulæ give proportions for various sizes of ropes.

$$
\begin{aligned}
D &= \text{diameter of rope.}\\
A &= 1\tfrac{1}{4}\,D + \tfrac{1}{4}\,\text{in.}\\
B &= \tfrac{1}{8}\,D + \tfrac{3}{16}\,\text{in.}\\
C &= \tfrac{1}{4}\,D\\
E &= 1\tfrac{3}{8}\,D + \tfrac{3}{16}\,\text{in.}\\
F &= \tfrac{1}{2}\,D + \tfrac{1}{16}\,\text{in.}\\
G &= \tfrac{1}{4}\,D + \tfrac{3}{16}\,\text{in.}\\
H &= D
\end{aligned}
$$

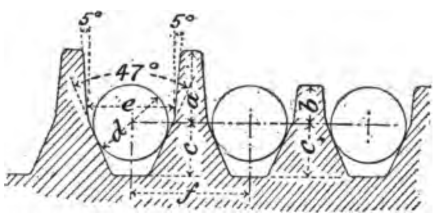


FIG. 229
Hunt Pulley Grooves.

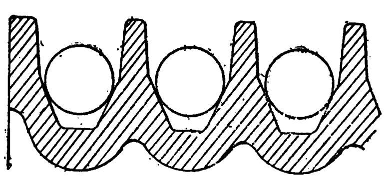


FIG. 230
Hunt Pulley Grooves.

The C. W. Hunt Co., of New York, adopt an angle of 47° for the sides of the pulley grooves for rope driving. The forms designed for deep and medium grooves are shown in Figs. 229 and 230 with their formulæ :—

d = diameter of the rope.
$a = D - \frac{1}{8}$ in.
$b = \cdot 5D$
$c = \cdot 7D$
$e = D + \frac{1}{4}$ in.
$f = 1{\cdot}375\ D + \frac{3}{8}$ in.

These grooves have an advantage over those with concave profiles, being more easily turned and measured.

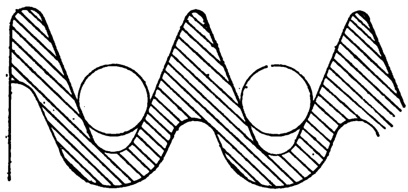


FIG. 231
Grooves for Crossed Ropes.

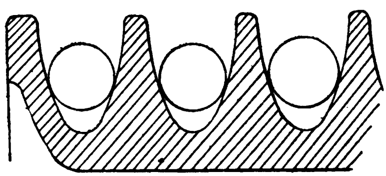


FIG. 232
Grooves with Curved Sides.

Fig. 230 also shows the Hunt deep groove, with the rim section as well. Another form of deep groove is that in Fig. 231, used for crossed ropes, where a single rope passes over multi-grooved pulleys. It will be noticed that the pitch is wider than in ordinary pulleys. Many pulleys have been made with curved grooves like those in Fig. 232, but it is generally recognized that the straight sides are better, and are more easily machined.

CHAPTER XIII

JOINTS AND PACKINGS

AMONG the last jobs which a fitter has to do, is to complete connections, and make joints. These are often made in haste, and if done clumsily cause annoyance by leaking, if water joints; and blowing out, if steam joints.

Scraped joints.—The ideal joint is that which is made by scraping. When properly made it is perfectly steam and watertight, and nothing more is done, except to smear it with a thin film of red lead and oil. Hence it is employed for the covers of engine cylinders and steam chests, and for sliding faces. But it is a costly joint—too costly for much of the work of the shops, and is therefore only reserved for high-class jobs.

Insertion joints.—Next in order there comes, for average work, rough-turned or planed faces, which, in themselves, are neither steam nor watertight, being covered with minute ridges. It is necessary to use some kind of *insertion sheet* with these. The materials used are wire gauze, American cloth, canvas, millboard, brown paper, indiarubber, other prepared material, or copper wire. But the thinner the material the better for faced joints; hence American cloth, canvas, and wire gauze are generally employed for these; and indiarubber and millboard for unfaced or coarsely cut surfaces. Indiarubber insertion sheet makes a good steam joint, but it is more costly than

the wire gauze, or the American cloth. It consists of indiarubber sheet, in the centre of which is inserted a sheet of canvas, the two being perfectly amalgamated. Asbestos sheet is used for the same purpose; but being costly, it is not employed to the same extent as the other substances. The insertion sheet is cut to the same diameters as the faces which have to be jointed, smeared with red lead and oil; thinly spread for faced joints, thickly for rough surfaces, and screwed up between them. With indiarubber against good faced joints the red lead

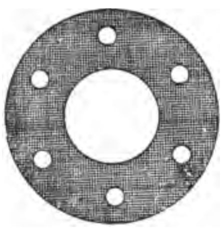


FIG. 233
Wire Gauze.

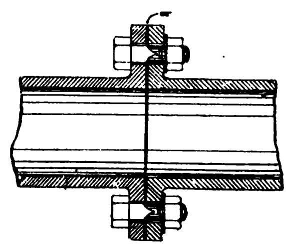


FIG. 234
Joint with Insertion Sheet.

may be dispensed with. It matters little how thick the coating of red lead is made for the joints of low-pressure water pipes; but much of it is objectionable for steam joints, because the steam acts upon it and causes a blow out to occur. Hence as little red lead as possible is employed in steam joints, and wire gauze is one of the most suitable materials to use on a rough-faced joint for steam. Fig. 233 illustrates a piece of wire gauze cut to fit between flange faces, and having the bolt holes also cut out. This is smeared thinly with red lead paste, and screwed between the flanges. Fig. 234 shows a section through a flanged joint made by one of these methods, *a* being the insertion piece.

Another way of making a steamtight or watertight joint on rough turned faces is to coil a bit of copper wire, say of about 20 gauge, round on the faces once or twice, allowing the ends to overlap well (Fig. 235, *a*) ; when the

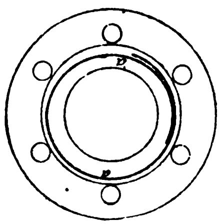


FIG. 235
Jointing with Copper Wire.

flanges are screwed up tightly the wire becomes squeezed and flattened out, and effectually prevents the passage of steam or water. The bolts must be tightened regularly in succession to produce equal pressure all round. The

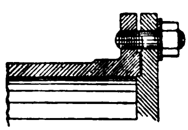


FIG. 236
Joint with Copper Wire (Section).

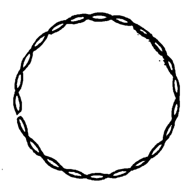


FIG. 237
Plaited Tar Twine.

copper wire is useful on narrow joint faces like that shown in Fig. 236, common on many engine cylinders.

When rough, unfaced flanges have to be made steam or watertight, then insertion washers of millboard, india-rubber, or asbestos, of considerable thickness, say from $\frac{1}{16}$ in. to $\frac{1}{8}$ in. have to be inserted and well smeared with a thick

paste of red lead and oil. Being thick, they accommodate themselves to the inequalities of the surfaces, and the red lead helps further to fill them up. If flange faces are very uneven, and their joints lapping, then some shaving off of the insertion sheet in some places may be necessary. Years ago plenty of these rough joints used to be made; but it is the practice now, and is cheaper and better, on the whole, to rough-face such joints, except, perhaps, in the case of a bit of casual jobbing work.

A good steam joint is often made between faced flanges by the introduction of a bit of tar twine, well smeared, and inclosed with red lead paste, and coiled round in the joint face in a similar manner to the copper wire in

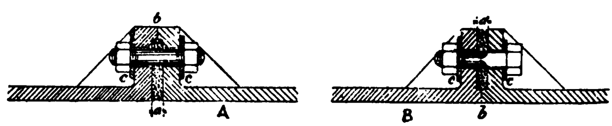


FIG. 238
Rust Joints.

Fig. 235. Being squeezed and flattened out, it answers the same purpose as the copper.

A perfect steam and watertight joint between rough surfaces is often made by plaiting tar twine in the manner shown in Fig. 237, inclosing it in red lead paste, and inserting it between faces which are pulled up with screw pressure. This is used on flanges sometimes, and generally for making the joints of the man-holes and mud-holes of steam boilers.

Rust joints.—These are shown at Fig. 238, A and B. They are the joints used for tank plates. The only difference in the two figures is that A is caulked from the inside of the tank, B from the outside. The faces of the

flanges are separated by a distance, *a*, of from $\frac{3}{8}$ in. to $\frac{1}{2}$ in., and this is the space which is filled up with rust cement. There are fillets, *b*, cast upon the flanges to retain the cement, and prevent it from becoming forced out before the pressure of the caulking tool. The cement consists of iron borings mixed with water, in which a small portion of sal-ammoniac—an ounce or two to the cwt. of borings—is dissolved. It is driven in tightly with a blunt-pointed caulking tool and hammer blows. At A stud bolts are shown, at B common bolts are used with square necks.

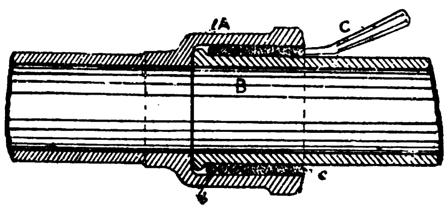


FIG. 239
Socket Joint.

Iron washers are shown at *c*; often, however, gromets, or grummet washers, are employed, being made of twisted tar twine. The bolts are always slack fits in the rough cast holes, and the gromet washers help to render them watertight against almost any pressure without leakage. Of course loosely-fitting bolts are only employed on rough work, never for the best fittings.

Socketed joints.—The socket or faucet form of joint is employed chiefly for water and gas pipes. There are three ways of making these tight. One is to caulk or *stem* them with molten lead, another with sulphur or with Portland cement; a third less used as yet, by turning and boring taper. Fig. 239 shows a caulked joint; the socket A being slid over the spigot B. Spun yarn, *b*, or gasket

is first coiled round and hammered in tightly, and then the space remaining is filled with molten lead, *c*, hammered or stemmed in fast with a blunt caulking tool, C. As this is done when the pipes are laid in place, stiff clay is lapped around the pipes to confine the lead, and prevent it from running away as it is poured in from a hand ladle. Sulphur is seldom used, and turned and bored joints are not so well adapted for jobbing work. Of late years, however, the practice has been adopted to a large extent of boring the sockets, and turning the spigots to make close contact through a short portion only of their

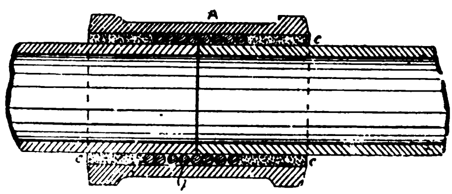


FIG. 240
Thimble Joint.

length, which permits of considerable adjustment of the pipes.

When old lengths of pipe have to be inserted in positions where a regular socket and spigot length cannot conveniently be used, then what is termed a *thimble* is used to effect the union. This is really a double socket, not necessarily, though sometimes shouldered at the middle. It is a cast-iron sleeve, Fig. 240, A, slipped over the cut or broken ends of the pipes to be united, and caulked from each end with spun yarn, *b*, and with lead, *c*.

To fill up the socket of a pipe already in position, in order to save the trouble of making a new pipe with a blank end, a *stop* A, Fig. 241, is inserted. This is also

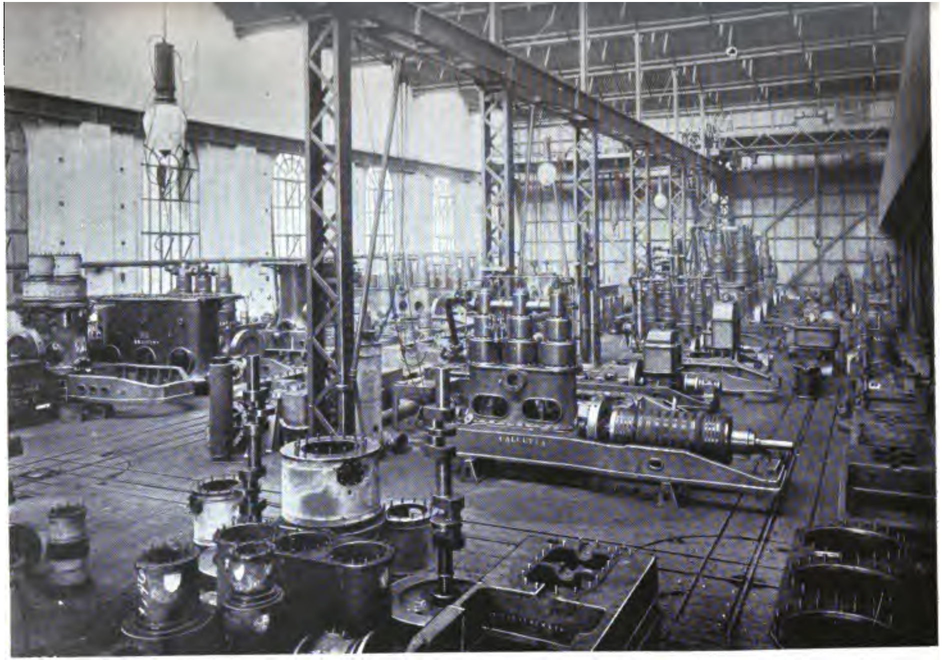


PLATE 6.—Shop of Willans and Robinson, Ltd., Rugby. [Facing p. 288.

caulked around like the socket and spigot joint, and the beading prevents the escape of the lead, as in the case of the similar beading in Fig 239.

Necessarily, sufficient space must be left for caulking. It is better to let this allowance be rather in excess than otherwise, as it is difficult to use the caulking tool in a narrow space. From ½ in. to ¾ in. all round is the allowance usually given. The size of a socket, a thimble, or of a stop, is always given in terms of the size of pipe for which

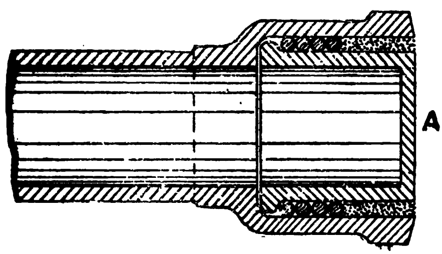


FIG. 241
Stop.

they are used. Thus a 3 in. thimble will measure about 4½ in. in the hole, to fit round the spigot of a pipe 3 in. in the bore. A 3 in. stop will be 3 in. in the hole.

Of late years large pipes have been made in steel and in wrought iron, instead of in cast iron. Flanges of angle iron are sometimes used, but usually socket joints are employed. Fig. 242 shows one method of making socketed and spigoted ends. The socket A is formed of steel riveted to its pipe. A recess, *a*, assists in holding the cement. Sometimes, in pipes of not very large diameter, sockets of cast iron are employed, and riveted to the pipe.

Fig. 243 shows a form of watertight joint easily detachable, employed for wrought iron or steel tube of large

diameter. Rings of cast iron, male A, and female B, are fastened with rivets *a* to the tubes. The opposite faces of the checked portions are vee'd, to inclose the ring C of indiarubber, which renders the joint watertight. Each

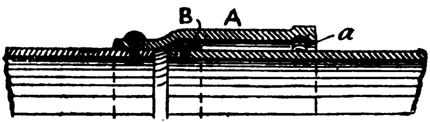


FIG. 242
Socket for Steel Pipe.

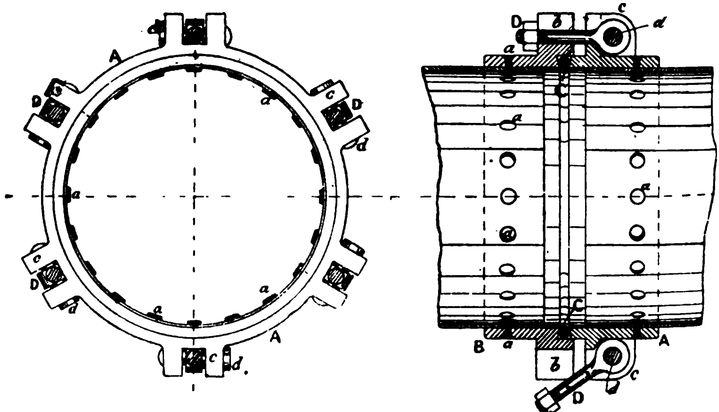


FIG. 243
Joint for Wrought Iron Pipe.

ring is provided with lugs, *b* and *c*. Eye bolts D are pivoted loosely into the lugs *c* with rivets *d*. They fall over into the recess between the lugs *b*, and the nuts are tightened against the outer faces of the lugs *b*. One of the bolts is shown at the lower part of the figure dropped out of its lug. In this way the bolts are loosened when the pipes have to be separated. The faces of the flanges

never come together, but the whole pressure of the bolts is exerted against the indiarubber ring C. These flanges are used with pipes of iron and steel, and for flexible tubing of indiarubber, the rubber being slipped over the ends of short lengths of pipe attached to the flanges, and secured with copper binding wire.

Expansion joints.—Fig. 244 shows a special method of jointing steam pipes when they extend to considerable length. If such pipes were fastened rigidly with socket

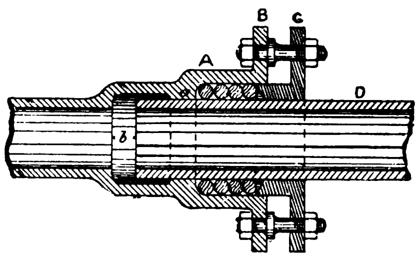


Fig. 244
Expansion Joint.

and spigot, or with flanged joints, they or their connections would become fractured by shrinkage or expansion due to the extremes of temperature to which they would be subjected. An expansion joint, therefore (Fig. 244) is interposed between the rigid connections. It comprises on one pipe an enlarged socketed end, A, with flange B, and gland C, within which the other pipe, D, slides. A, therefore, forms a stuffing-box, and is packed just as an engine stuffing-box is packed. The end of the pipe D is turned, and has its bearing in the gland C, and on the annular neck *a*. Sufficient clearance is left at *b* to permit of free endlong movement of the pipes.

Packings.—Packing with spun yarn is one of the commonest jobs.

Fig. 245 illustrates the manner in which stuffing-boxes are packed with spun yarn or gasket to render them steamtight. The nuts are run off the stuffing-box studs *a*, and the gland A slid back along the piston or pump rod B sufficiently far to allow the workman to get at the stuffing-box. The spun yarn C is well greased, and then wound round the rod two or three times, and forced inwards tightly with a caulking tool or a key-drift; then it is wound round again and forced in and so on until the

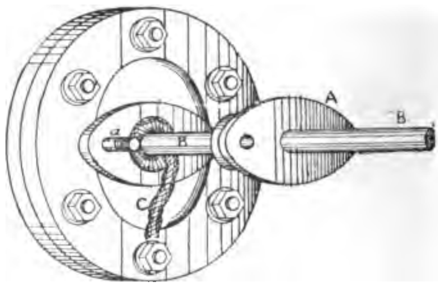


FIG. 245
Packing a Stuffing-box.

stuffing-box is full of the packing. The figure shows the operation at this stage. Then the gland is brought along to the front of the opening, and the nuts put on. A few turns of the nuts force the gland a very little way into the stuffing-box, squeezing the packing inwards, and from time to time the gland has to be tightened to compensate for wear, until at last it is brought close to the face of the stuffing-box flange, and then the box has to be repacked.

The metallic packings have largely superseded the old-fashioned kinds, and they are fitted to most good engines. One of the best types is that made by The United States Metallic Packing Co. Ltd. of Bradford, and shown sectionally in Fig. 246. The steamtight joint is made between

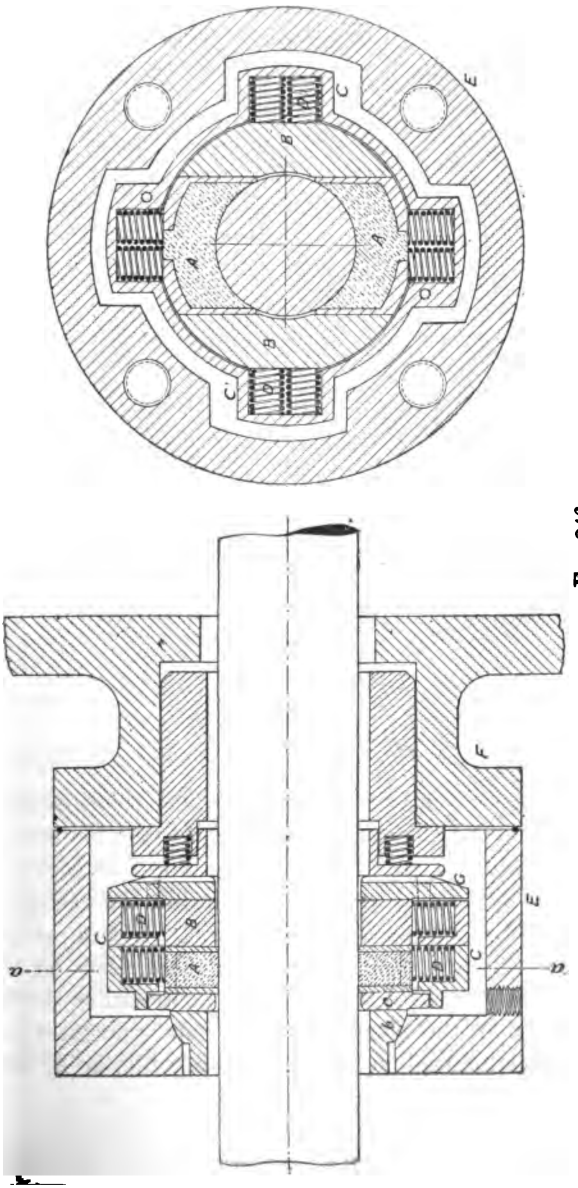


FIG. 246
Metallic Packing.

blocks of Babbitt metal A, of which there are four, in pairs set at right angles with each other. These blocks are held in thin castings of gun metal, and are confined laterally by blocks B, which do not touch the piston rod. Coiled springs D maintain a constant pressure upon the blocks, which all lie within their casings C, C. At the front end there is a ball socket *b*, fitting inside the body

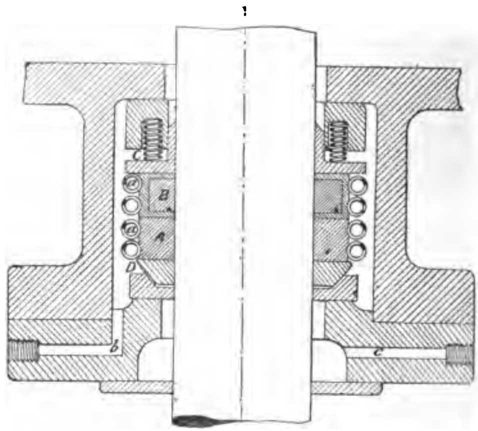


FIG. 247
Metallic Packing.

E, and against which the plate *c* rests. The whole packing is therefore able to float and adjust itself to the rod, should the latter ever get out of alignment. The ball socket is kept close by several springs seen inside the casing F, pressing against a plate which touches C. Steam can get inside the casing E, from the cylinder, and press on the outsides of the blocks A, so that they press harder on the rod the higher the steam pressure; but they are also checked by the friction of the flanking blocks B, also

acted on by the steam, so that the pressure on the rod, from A, does not become excessive.

A packing made by Messrs. Lancaster & Tonge, Ltd. of Pendleton, is shown in Fig. 247. Here sectional blocks, A B, filled with Babbitt, are closed in around the rod by coiled springs *a*, *a*, embracing the outside; the tension of the springs may be altered by unhooking their ends, and turning them to right or left to increase or diminish the strength. A plate with springs, C, gives endlong pressure which is received at the other side by a ball-and-socket

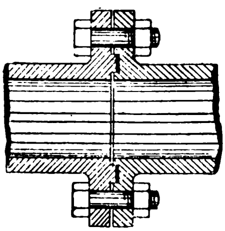


FIG. 248
Checked Flanges.

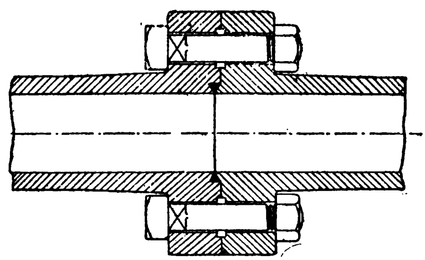


FIG. 249
Hydraulic Joint.

arrangement D. The outlet *b* is a drain, and that *c* is for oil.

Hydraulic pipe joints—It is a waste of labour to check flanges into one another, except for heavy hydraulic pressures. Except for these, flanges properly faced and bolted together with turned bolts are secure. There are many methods resorted to for confining the packing material in place. A simple and much-used form of checked flange is shown in Fig. 248. A recess is bored in one flange, and a corresponding projection on the other. A ring of lead, indiarubber, or guttapercha is squeezed into the recess and makes a perfectly watertight joint.

Hydraulic joints, such as in Fig. 249 for high pressures are turned with a check, and a vee space, into which a rubber ring is inserted to make a watertight joint.

Fig. 250 illustrates a flange joint employed in hydraulic work, both for high and low pressures. It consists of male and female flanges of gland-shaped outline, cast upon the ends of cast iron pipes. They are checked one into the other and slightly bevelled on their opposed edges. A ring of indiarubber or of guttapercha of circular section is inserted between these opposed faces, and when

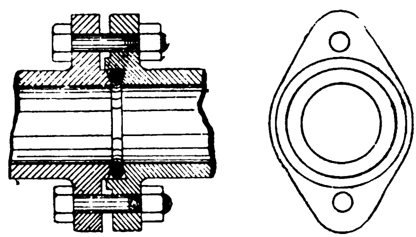


FIG. 250
Male and Female Flanges.

the flanges are pulled together with their bolts, the squeezing of the ring renders the joint perfectly watertight, while the bevel of the edges tends to force the ring outwards, so closing the joint completely.

Steel flanges riveted to steel piping is a usual practice, Fig. 251, the flanges being held together with bolts.

Pipes of moderate and small diameter may be screwed, and the flanges fitted on the ends, Fig. 252, so dispensing with riveting.

Wrought iron pipes and copper pipes.—These are employed to a very large extent in almost all engineers' work. The iron pipes are used in various thicknesses for low and for high pressures, for water and for steam, and they are

welded, and solid drawn. The copper pipes are employed chiefly for steam, and are brazed, solid drawn, and

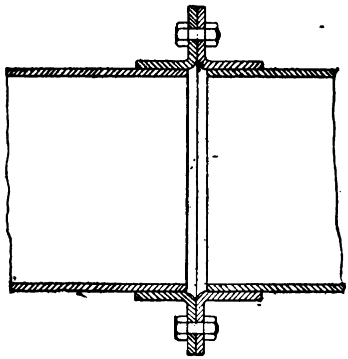


FIG. 251
Steel Flanges.

electrically deposited. The fitter's work consists in cutting off, bending, and fitting flanges and sockets to such

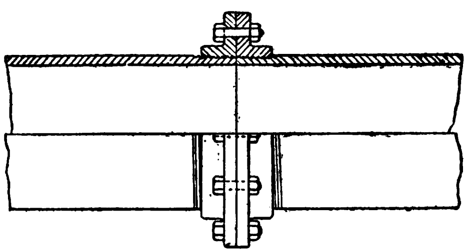


FIG. 252
Screwed Flanges.

pipes. In large shops such jobs are done by pipe fitters and plumbers exclusively. In small firms fitters are expected to be able to do such work.

Pipes are cut off with a pipe cutter, the cutting being

done with the small hardened steel wheel with vee'd edges in the jaw of the cutter. This being worked around the pipe several times with the leverage afforded by the handle, forms a groove, and so severs the pipe. The pipe is held in a vice the while.

Methods of connecting-up wrought iron tubing for steam and water are shown in Figs. 253–266. There are but a few common forms and joints, and from these any connections required can be made.

Fig. 253 illustrates a typical piece of pipe fitting, into which nearly, though not quite, all the common fittings are introduced. It contains *straight tubes* A, *bends* B, *elbows* C, *tee piece* D, *sockets* E, *nipple* F, and *back nuts* G. At H cast iron flanges are shown, by means of which the piping is connected to other flanges on cast or wrought iron work.

Straight tubing A is made in many lengths, from 24 in. up to 14 ft. It is either plain, and screwed externally at each end, or it is formed with an external screw at one end —the *spigot*, and an internal screw at the other—the *socket*. When a tube has to be bent, the bending may be effected in a long, flat curve, B, or in a very quick or abrupt curve, C, the latter often taking the form of a complete right angle. When practicable, the former is always preferable, because there is less loss by friction than there is with a quick bend; but the employment of the latter is often unavoidable, in consequence of the pipes having to clear some other portions of the mechanism adjacent. For very flat curves the long, flat bends, termed "springs," are employed. These are either regular curves, or curves combined with a straight length. They fulfil similar functions to the eighth and sixteenth cast iron bends.

When two or three irregular bendings in different

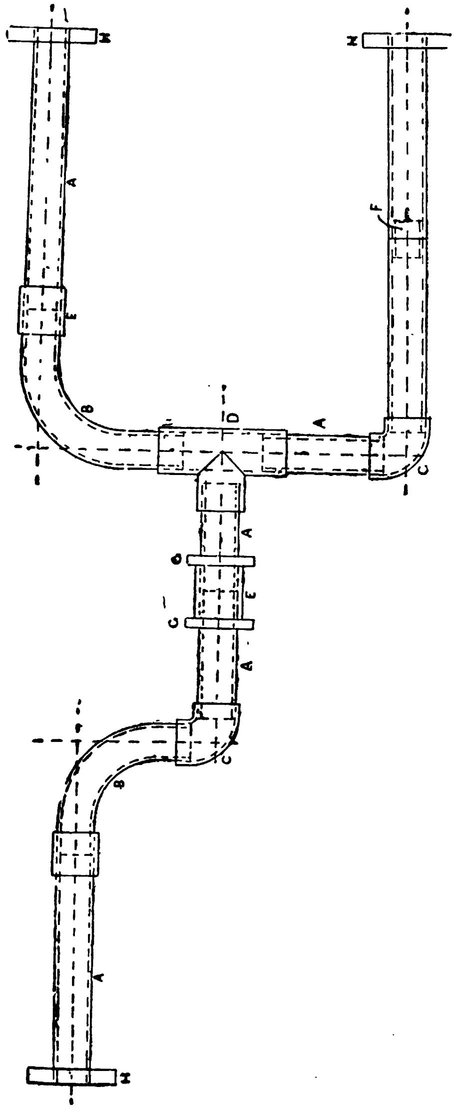


FIG. 253
Typical Wrought Iron Pipe Fitting.

planes are required in a length of pipe for the purpose of clearing portions of mechanism, then it is the practice, instead of screwing bends to the straight pipes in the manner

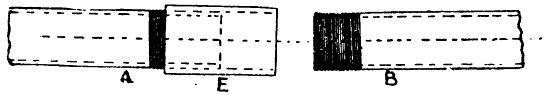


FIG. 254
Socket Connection.

already described, to form the bends in the straight pipe in the way to be presently described.

Pipes and bends are connected with screwed sockets, E. A socket connection between two pipes is shown enlarged in Fig. 254. The socket E is screwed upon pipe A, and B is ready for connection. If the outside expansion is of no importance, the plain socket E is used upon the outside. But if pipes and bends have to be connected, and yet be flush outside, the nipple, Fig. 253 F, is used. This, of course, slightly diminishes the passage-way in the pipe, but is usually of little consequence. Fig. 255 shows two elbows, C, connected with a nipple, F. The elbows may be turned into different planes if required.

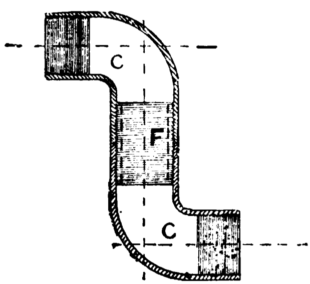


FIG. 255
Nipple Connection.

When three pipes have to be connected at right angles, the tee, Fig. 253, D, and Fig. 256, is used. It is often the case that one branch of the tee does not require to be utilized for a while. In such a case the *plug* J is screwed into the opening, to close it until a connection requires to

be made. If four pipes have to be connected, a *cross* is used. This is like a tee with an additional branch, shown dotted in Fig. 256.

To connect two pipes of different diameters, the *diminishing socket*, Fig. 257, is employed. It is, of course, of wrought iron, screwed at each end internally.

Two pipes often have to be connected in such positions that one cannot be turned into its fellow with the pipe

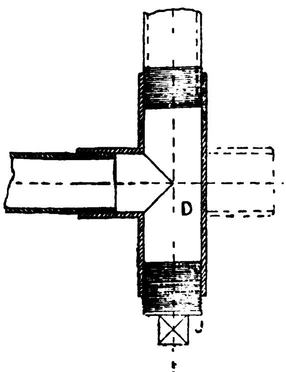


FIG. 256
Tee Piece.

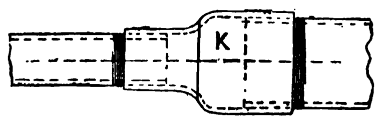


FIG. 257
Diminishing Socket.

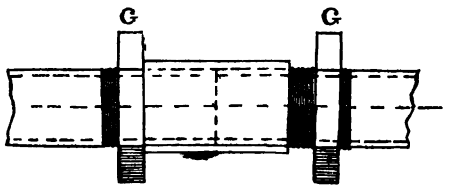


FIG. 258
Back Nuts.

tongs. Then a plain socket, with what is termed a *running thread*, that is, an easily-fitting thread is used. In order to make the pipes watertight, in such cases, back nuts, Fig. 253, G, and Fig. 258 are brought up behind the socket, and made fast with a few threads of hemp and red lead laid into the screw threads. In the figure the right-hand nut is shown ready for running up, the left-hand one being already in place.

Pipe bending.—Iron pipes are bent while red hot, copper pipes are bent cold. Iron pipes are filled with

sand at the sections which have to be bent, in order to prevent crumpling and corrugation on the inner curve; frequently, however, nothing is put in the pipe. If it is bent slowly and regularly, the surface will retain a smooth and even contour. The manner of bending makes more difference in the result than the employment of sand, or omission to use it. It is the same as with glass tubing: irregular heating and too quick bending will produce crinkles, equable heat and steady bending will give a regular curve. Copper pipe is bent cold. It is usual to pour melted rosin into the pipe, and when this is cold, to bend the pipe; after bending, the rosin is melted out.

Templets.—Before bending pipes, it is usual, in most cases, not to trust to rule measurement, but to make templets of the lengths and curves of the pipes required. In fact, it would be well-nigh impossible to take measurement of the curves of many pipes, because of the numerous bendings, in different planes which they have to make. For pipes in copper and iron it is usual to make templets of wood, or, more commonly, of iron rod, the former by the pattern maker or carpenter—the templets being similar to those employed for pipes of cast iron; the latter by the fitter himself. Wooden templets consist of strips of thin wood, sawn roughly to the outlines of the pipe, and having sawn flanges nailed and bracketed upon the ends in the same position as the flanges which are required on the iron pipes. The iron templet, Fig. 260, consists of a bit of $\frac{1}{4}$ in. or $\frac{3}{8}$ in. round rod, bent to the required curvatures of the pipe, and having sheet iron flanges, B B, riveted on the ends, also corresponding in size and position with the flanges which have to be screwed or brazed upon the iron or copper pipes. In a wooden templet the outside edges of the strips usually

correspond with the outside of the pipe; in an iron templet the rod corresponds with the centre line of the pipe.

Small pipe flanges.—Flanges for iron and copper pipes are either circular or gland shape in form. They are

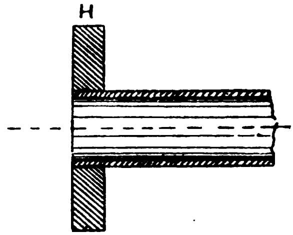


FIG. 259
Screwed Flange.

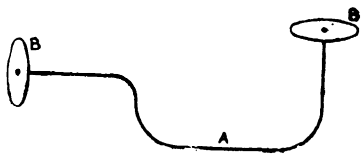


FIG. 260
Pipe Templet.

screwed upon iron pipes, Figs. 253, 259, but brazed upon copper tubes, Fig. 261. For iron they are made of cast or of wrought iron, for copper of brazing metal. They are made of substantial thickness in each case, in order to give sufficient thickness for the screw threads to hold well,

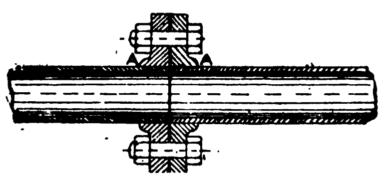


FIG. 261
Brazed Flanges.

and to stand the pressure of the bolts. Cast iron flanges are seldom less than $\frac{3}{4}$ in. thick, and range to $1\frac{1}{4}$ in. Small flanges are made in wrought iron for greater strength, and range from $\frac{1}{2}$ in. to $\frac{5}{8}$ in. in thickness. Flanges in brazing metal are made thin for economy of material; but are almost invariably thickened up with a boss (Fig. 261, A A) around the hole, in order to give sufficient surface for

brazing. Fig. 261 shows two such flanges brazed on their copper pipes and united with bolts.

The flanges for copper pipe being brazed on, and not screwed, are made in brazing metal, composed of 98 copper, 2 tin, to stand the heat necessary for brazing. The operation is as follows. The flanges are faced and then bored to make an easy, but not a slack fit, with the outside of the pipe. Spelter is pounded up small, and mixed with burnt borax mixed with water. The pipe is slung in a chain over a clear coke fire, and the spelter and borax ladled around the joint, and the heat raised with blast to the fusing point of the solder. Fresh solder and borax are added where necessary, and when it is run into the joint, the pipe and flange are lifted away from the fire and cooled in water. Rings and collars are brazed on in similar fashion.

Unions.—There are other forms of joints termed unions, some of which are shown in succeeding figures. Fig. 262 is a union employed to connect wrought iron tubing to a nozzle of cast iron or gun metal. A is a collar screwed upon the wrought iron tubing; B is a hexagon nut making a close fit with the outer diameter of the iron tubing, and screwed internally to receive the nozzle C; D is a leather washer which makes a watertight joint on the screwing up of B over C.

Fig. 263 shows a way of connecting copper tubing. A is a collar brazed on one tube; B is a collar brazed on the other; C is a hexagon nut screwed internally to fit over B. The left-hand end of B is of hexagon shape. A leather washer, D, is interposed between A and B.

Fig. 264 is a joint for copper pipe subjected to hydraulic pressure. A is a screwed socket on the main casting. B is a nozzle screwed to fit the thread in A, and provided

with a hexagon head at B. B is brazed to the copper pipe C, and is screwed and soldered also into A. A small recess *a*, filled with solder, or with a guttapercha ring, also helps to render the joint more secure. These screwed and

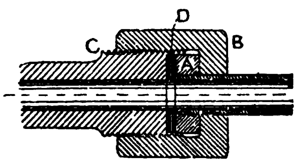


FIG. 262
Union for Wrought Iron Tubing.

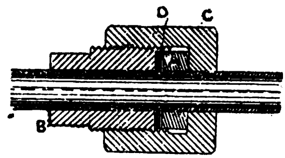


FIG. 263
Union for Copper Tubing.

soldered joints are chiefly made use of in hydraulic pumps and fittings subjected to high pressure. The water would become squeezed out through plain turned and bored joints, or through screwed joints, without solder. The nuts, which are inserted above three winged lift valves

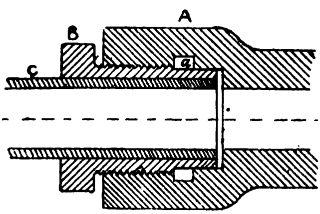


FIG. 264
Union subject to Hydraulic Pressure.

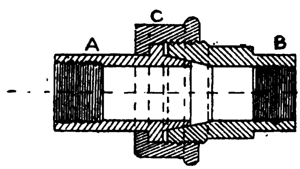


FIG. 265
Common Union.

in hydraulic pumps, are also screwed in this way and soldered.

Fig. 265 is a mode of union for iron or brass tubing. There is a nozzle piece A, a socket piece B, and a nut C. A and B are screwed internally to receive the tubing. The collar of A fits in the shoulder of C, and the screwing up of B into C makes a watertight joint of the coned

nozzle and socket. Of these union joints there are a great number of modified forms. Thus in Fig. 265, A and B are as often screwed externally to receive female-threaded piping; or A and B will be smooth internally and externally for the union of lead or brass tubing by soldering. These are then termed ferrules. Grooved or vee'd externally, they are used for indiarubber hose. Frequently then the nut is dispensed with, and two pins standing out from opposite sides afford the necessary leverage for screwing up. The indiarubber tube embraces the grooved or vee'd exterior of the nozzle, and is secured either with brass or copper binding wire, or with clips of brass or copper.

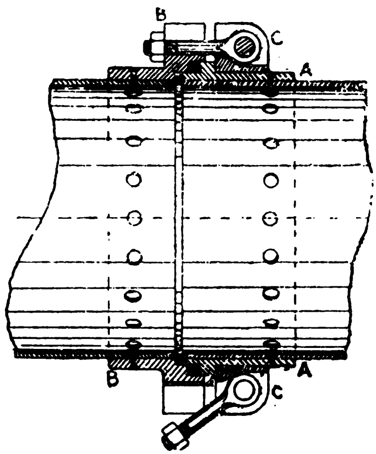


Fig. 266
Swivelling Joint for Wrought Iron Pipes.

Fig. 266 is a swivelling joint for large wrought iron piping. It is a modification of the joint shown in Fig. 243, p. 290. But instead of two rings, A and B in that figure, there are three, A B C. In this case there are no lugs on A, which is simply a plain ring riveted to its pipe and provided with a shoulder *a* to receive the pull of the ring C, which has lugs corresponding in centres with those on B. The two pipes can therefore be swivelled in relation to one another, the eye bolts falling within either of the lugs indifferently. These joints are used

both for wrought iron and steel tubing, and for hose pipes.

Pipe threads.—Iron pipes are screwed with gas threads. The size of the gas thread is given in terms of the bore of the pipe. Thus, for example, what is called a 2 in. gas thread is not, like a Whitworth thread, 2 in. in diameter, but 2·347 in.—2·347 in. being the outside diameter of a 2 in. pipe. Holes are tapped, and pipes screwed both in the lathe with change wheels, and with gas taps and dies. In shops as much work as possible is done with a special screwing machine fastened to an ordinary work bench. After the threads are cut, the joint is made steam or watertight by an application of red lead and oil worked into a paste, and with threads of hemp, screwed down tight with the pipe tongs.

Hydraulic packings.—Hemp packings are often employed for pumps, being less costly than leather, and in certain cases, for low pressures, they form a useful substitute. There are, however, two objections to their employment. One is that the pressure which they exert upon the ram or plunger is constant, being that due to the screwing down of the gland, and if the ram is working at a low pressure, the friction of the ram is not correspondingly low, but excessive in amount. But the pressure on a leather packing is just proportional to the liquid pressure for the time being. Moreover, hemp packings at high pressures score the sides of the rams or plungers much more than good leathers will do.

Leathers.—Leather packings are used for pumps and rams. There are three forms employed: the cup leather, Fig. 267; the U leather, Fig. 268; and the hat leather, Fig. 269. The first two are in most frequent use.

Figs. 270 and 271 illustrate two methods of using cup

leathers. The first figure is the bucket of a lift pump, the second is the ram of a force pump. The upper part of Fig. 270 shows the outside of the bucket; the lower part shows the bucket in section. These parts are: A, the

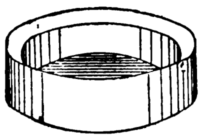


Fig. 267
Cup Leather.

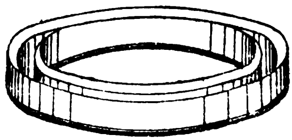


Fig. 268
U Leather.

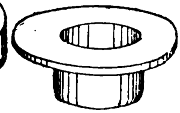


Fig. 269
Hat Leather.

body of the bucket, of which the diameter A^1 fits the bore of the pump barrel; B, the flap valve; C, the hole in the bottom of the bucket for the ingress of liquid; D, the cup leather; E, a guard ring, the function of which is to confine the leather in place, screws F passing through the

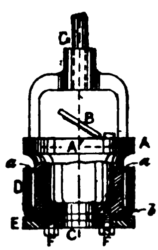


Fig. 270

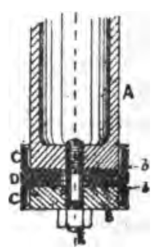


Fig. 271

Cup Leathers.

ring and leather into bosses cast in the internal bottom flange of the pump body. G is the pump rod. A narrow clearance is left at *a a* between the leather and the pump body, and the liquid filling this up under pressure, forces the leather outwards against the sides of the barrel, rendering it watertight. In the other example (Fig. 271)

two leathers placed back to back, with a guard ring placed between, are used. In this figure A is the plunger body, B is the block by means of which the leathers are tightened, C C are the leathers, D is an intermediate guard ring of brass, which affords support to the convex edges of the leather. Two leathers are used in this case, because the liquid pressure acts in both directions of the plunger. In Fig. 270 the pressure acts in one direction only. The method of securing the leather by means of the

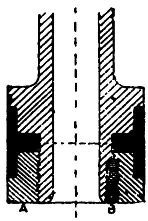


FIG. 272
Cup Leather.

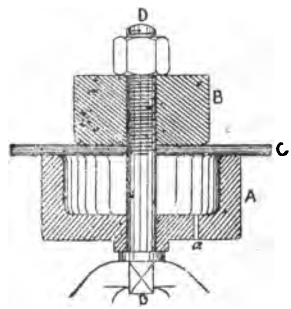


FIG. 273
Moulding a Cup Leather.

stud E and nut is one example only. Sometimes the end of the plunger is prolonged, as in Fig. 272, a nut, A, screwed over it, and secured with a set screw, B. The depth of the leathers is not of much importance, because, practically, they only wear at the corners, *b b*, Figs. 270, 271.

Making leathers.—The packings are either bought, or made in the shops. They are easily made. The leather should be of sound quality, and be first cut into discs of the diameter required to bend the cups from, and soaked in warm water until rendered quite pliable. They are then pressed into moulds of cast iron in the manner shown

in Figs. 273 and 274. Fig. 273 illustrates the commencement, Fig. 274 the termination, of the operation. The reference letters indicate the same parts in each figure. A is the mould, the internal diameter of which corresponds with the outside diameter of the leather C; B is a block, the diameter of which equals that of the internal portion of the leather C; D is the bolt by means of which the leather is squeezed into the cup. In Fig. 273 the leather disc C is placed upon the mouth of the cup, and the square neck of the bolt D being pinched in the vice, the bolt is prevented from turning while the nut is screwed down upon the block B, thus gradually forcing it down upon the leather, and the latter into the cup A. The hole *a* allows the imprisoned air to escape, otherwise the leather could not be pressed down completely into the mould. When finished, as in Fig. 274, the nut is run back, the block B removed, and the leather allowed to dry. When dry the edges are chamfered with a knife to the angle of about 45°, and it is ready for use.

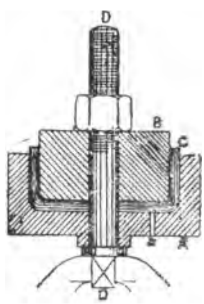


FIG. 274
Moulding a Cup Leather.

The U leathers are made in two stages (Figs. 275, 276). At the first stage (Fig. 275) the leather A is pressed into the cup form in the die B, with the hollow block C, a hydraulic press being employed for the purpose. At the second stage (Fig. 276) the U form is completed by coercing the leather between the additional dies D and E, and finishing it into a hat form with a U section at the edges. The central disc is afterwards cut out, and the edges chamfered to an angle of about 45°.

The method of formation of the hat leather is shown in Figs. 277, 278. A is a block the boss of which is of the same size and shape as the interior of the leather; B is an

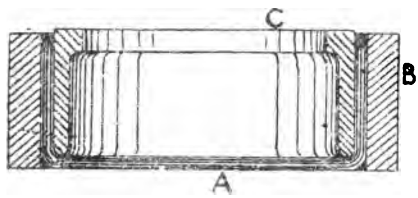


FIG. 275
Moulding a U Leather.

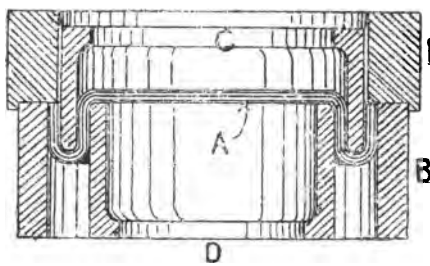


FIG. 276
Moulding a U Leather.

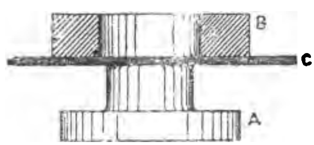


FIG. 277
Moulding a Hat Leather.

annular block of the same interior diameter as the outside of the leather; C is the leather disc, cut sufficiently large to press the leather out of. Fig. 277 shows the relative positions of A B C at the commencement of pressing; Fig.

278 at the termination of the same. Finally the central disc *c* is cut out, and the edge chamfered.

Inserting a **U** *leather.*—The cup packing just described is employed for buckets and rams, the **U** packing shown in

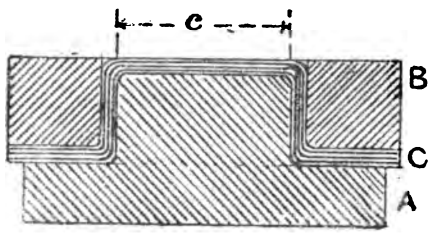


Fig. 278
Moulding a Hat Leather.

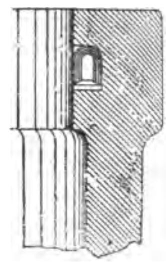


Fig. 279
U Packing.

Fig. 268 is used as a lining for rams or plungers to work in. The simplest method of inserting a **U** packing is shown in Fig. 279, where a recess is turned in the bore of the cylinder for the reception of the ring. Unless the ring is of large size there is a difficulty in inserting it. The

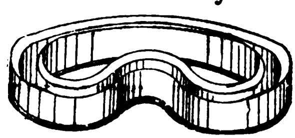


Fig. 280
Method of Inserting **U** Packing.

only way to do so is to pour some oil into the groove, and let it stand sufficiently long to render the leather supple; then bend the leather inwards at one side, in the manner shown in Fig. 280, when it can be thrust into the mouth of the cylinder. The convex part is then thrust into one side of the recess, and the concave portion opened out and

driven with one or two hammer blows into the opposite side, so filling it up completely.

When practicable, however, a stuffing-box and gland should be prepared, and the leather inserted without bending, as in Figs. 281 and 282. Fig. 281 is a large iron cylinder; Fig. 282 a small gun metal pump; hence the difference in the thicknesses of metal. In Fig. 281 a ring

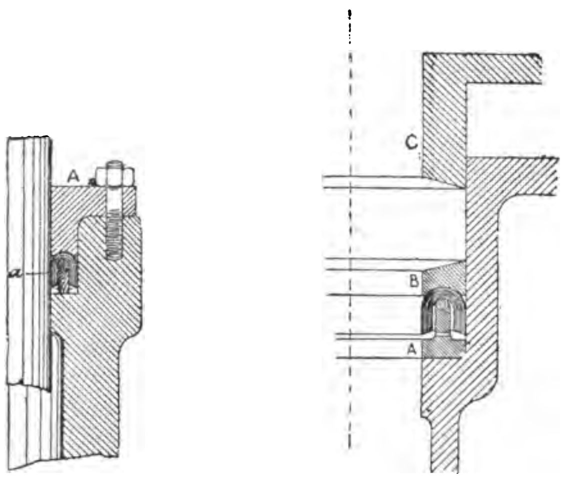


FIG. 281 FIG. 282

U Packings with Stuffing-box and Gland.

of wood, *a*, with grain running vertically, is inserted in the hollow of the ring, and the gland A is screwed directly down upon the leather. In Fig. 282 the leather ring is held between two gun metal rings—one within, A, one on the convex face, B; and the gland C being screwed down with hemp packing intervening keeps the leather in position. Note the small holes through the ring A for the water to pass to the farther side of the leather.

Shrinking on.—Another method of securing work firmly

is by shrinking on. The webs of built-up cranks are shrunk over their pins in this manner; so also are the tyres of railway and tram and crane wheels shrunk over their centres. A definite allowance, deduced from previous experience, is made for this, and the temperature is regulated accurately by sight. The heat for shrinking on is a low red, and the allowance may roughly average $\frac{1}{16}$ in. in from 2 ft. to 3 ft. in diameter.

CHAPTER XIV

SLINGING AND LIFTING

WE now consider that section of fitting and erecting which has to do with the lifting and hauling about of heavy work while in course of erection in the shop and in the yard. There is a great deal more involved in this than appears at first sight, and a man who is skilful in slinging and hoisting, securely and with rapidity, and in tying ropes, will get through his work much more quickly than one who is deficient in that kind of skill. Especially is this the case in out-door work. Though in shops there are usually ample appliances for lifting, such is not the case in places where work has to be finally erected.

Slinging.—First, of slinging in general. Ropes and chains are used for the purpose, some men preferring one, some the other. There is no doubt that, as a rule, ropes are preferable to chains. The latter are apt to become crystallized, and to develop incipient fractures by the stress of constant service, and to break without giving warning; but a rope will show signs of yielding before fracture. Besides, a rope is more elastic than a chain, and laps round the work better.

The sizes of sling ropes and chains vary, according to the bulk of the work which has to be lifted. In a well-equipped shop there will be all sizes kept, and the workman soon knows just what size to use for any given load taking care always to have plenty of margin of strength.

Sling chains vary in diameter from $\frac{1}{4}$ in. upwards. Being in constant use, they develop crystallization in the course of a few months, in which condition they are very liable to sudden fracture. It is the practice, therefore, to heat them in a reverberatory furnace or core stove, or over a wood fire, and allow them to cool down gradually.

Chains deteriorate, but less from corrosion, as some might suppose, than from a fatigue of the material, which reduces the originally fibrous and tough iron, to a brittle condition. Corrosion can be delayed by occasional applications of boiled linseed oil; but the crystalline deterioration goes on. It manifests itself in the sudden fracture of chains under loads less in amount than those which they had borne before in safety. To avoid risk of this, it is necessary to examine chains periodically—say once a year or oftener—inspecting each link singly, and tapping it with a hammer. If an incipient crack is present, the nature of the sound will indicate it. Any such links must be cut out.

But though the links may not show indications of faults, the chains must be annealed about once a year as a preservative.

Long chains, even though wound correctly on crane drums, develop twist in the course of time. To get it out all the slack chain must be run down and untwisted, coiling the chain on the drum again slowly free from twist. A common cause of this evil is the use of drums without grooves, and the coiling of more than one lap of chain. Having no grooves to fall into, the chain over rides, and becomes strained, and the evil is increased by letting one coil of chain lie on another.

Ropes.—The ropes used in the shops are of two kinds; hempen ropes, usually tarred, suitable for exposure to wet;

and Manilla, or white ropes, untarred, used only for indoor work. The tarred ropes should never be stowed away while wet, as that causes their strength to deteriorate. The hempen fibres from which ropes are made are from 3 ft. to 3½ ft. in length. The separate fibres, when twisted, form a *yarn*, several yarns compose a *strand*. Three or more strands, when twisted, form a *rope*. Thus, a *hawser-laid rope* consists of three strands laid up *right-handed*, or *with the sun*. A *shroud-laid rope* consists of four strands, laid up with the sun. A *cable-laid rope* consists of three hawser ropes laid up against the sun, or left-handed, with a small strand running through the middle, which is termed the *heart* of the rope. The twist of the strands is imparted in an opposite direction to that of the yarns, in order that their tendencies to become untwisted shall counteract each other.

The *bight* of a rope is its looped portion. The *standing end* of a tackle is that part which is fixed, the *running end* is its free end. The *fall* is the lower portion, to which the power is applied when hoisting.

Ropes are preferred to chains in some respects, for hoisting and hauling purposes. The principal reasons being as follow:

They are more flexible than chains, they coil evenly round a drum or sheave, while a chain is strained at every link, unless special forms of grooves are cast to receive the links lying flat and edgewise alternately, they stretch to a considerable amount before fracture, and so give indications of approaching danger. A chain link snaps without previous warning.

Ropes of manilla or cotton are used for the transmission of power. There is no difference in the value of each from the point of view either of their durability or

strength, provided they are equally well made, and employed under equally favourable conditions. These conditions are the use of pulleys of large diameter, long splices, ropes well lubricated, and not overstrained, and not driven at too high a speed. The rope forms rather a rigid structure on a short length, though flexible on a considerable length. When wound round a pulley the outer fibres of the rope being farthest from the centre are strained by being stretched, and as they pass round their pulleys many times in the course of a minute the result is that they are constantly being bent and straightened, and further strained. And the friction of the external fibres in the pulley rim, and of the internal fibres against one another, tends to wear the rope. The first is diminished by turning the pulley grooves smoothly, sometimes by lining them with wood, and by lubricating the rope; the second is lessened by having pulleys of large diameter in which the bending action is comparatively slight; and, in the practice of some rope makers, by lubricating the strands before they are twisted into yarns.

To run a rope at anything even approaching its breaking strength ruins it. It should never be strained beyond more than one-twentieth of its ultimate or absolute strength, reckoned at the splice. Its speed, though high, is usually limited to about 3500 ft. or 4000 ft. per minute, a rate which has been demonstrated by long experience as the best on the whole. Ropes must be kept dry, otherwise they will rot. If used out-of-doors they must be constantly lubricated.

Long splices are very essential. They should be from 9 ft. to 12 ft. in length. Short splices soon become pulled

asunder in wear. Splices must be very evenly made, and neither larger nor smaller than the rest of the rope.

Wire ropes.—If we compare the merits of the various classes of ropes—that is, hemp, cotton, or manilla for hoisting purposes—against those of wire, the balance is in favour of the latter. Hence we find wire rope taking the place of the other materials. The wire is more durable than hemp is, if properly cared for; the weight is much less for equivalent strength, and the cost is less. Wire rope moreover can be obtained in a very large range of strengths, while chain is practically of one strength only. Thus a chain made of $\frac{1}{2}$ in. iron will break at a pull of 7 tons. A tarred hemp rope of the same strength would have to be $5\frac{3}{4}$ in. in circumference, but an ordinary steel wire rope would be only 2 in. in circumference. But a wire rope might range in size from $1\frac{3}{4}$ in. to $2\frac{3}{8}$ in. in circumference to sustain this load, depending on the strength of the wire of which it is composed. From 80 to 90 tons per square inch is the average strength of the wire strands, but that can be increased up to 120 tons per square inch.

Flexibility is very necessary, and this is secured by making up a number of small wires into strands, and laying the strands up into ropes. From seven to twelve wires form a strand, the first having the seventh wire in the centre, and this forms a very rigid rope. Twelve wires are laid around a hempen core to form a strand, and six such strands laid round a hempen heart constitute a flexible rope. More flexible ropes are formed by laying twenty-four or thirty-seven finer wires to form a strand.

Pulleys for these ropes also are properly made not less than thirty times in diameter than that of the rope which

runs round them. This is but an approximate rule, since a good deal depends on the lay of the rope, its amount of sag, and the extent of the arc embraced by it, etc.; but it is an average rule for general practice.

Lifting tackle.—Other tackle, besides the ropes and sling chains, is employed in the fitting shops and yard. Usually over the benches, alongside of which work is erected, light wall cranes are fixed. These cranes are of types similar to that placed over the marking-off table, Fig. 130, p. 142 Their power will depend upon the class of work usually done in the shop, but it would seldom exceed 30 cwt. or 2 tons. These are not cranes in the strictest sense, but only swivelling jibs for carrying pulley blocks. The jib is horizontal, and its top edges form supports and guides for the travelling carriage, shown in Fig. 131, p. 143. The hook depends from this carriage, and it is to this hook that the pulley blocks are attached. The blocks are of the differential type, hence a load can be left suspended in any position without risk of its running down. Lifting with pulley blocks is slow work. Light shafts and castings are therefore frequently lifted by means of a single gin pulley suspended from the hook of the travelling carriage, affording no gain of power, but only a more convenient method of lifting than that which can be accomplished by mere hand lifting and clambering about the job.

For lifting weights which are beyond the capacity of the pulley blocks, an overhead travelling crane, or overhead traveller, is used in shops. There are several types of these travellers, such as the light class which is operated by means of an endless rope or small chain from below, which in turn actuates the gearing of the crab upon the traveller. This is not adapted for heavy loads. There is also the hand traveller, operated by a man, or men, upon the crab,

which travels along the gantry, which crab is fitted with fast or slow gearing to suit different loads. There is further the steam traveller, the action of which is much more rapid than that of the hand traveller; and also the cotton rope traveller; and finally the electric traveller, the best of all, and the one without which no modern shop can be deemed complete.

In outdoor work none of these appliances are available. When work is erected in an engineer's yard there is usually a Wellington traveller available for heavy work, This is a travelling crane, with vertical framings running on rails of large span or gauge. A top gantry carries a jenny or block carriage, by which the load is lifted and traversed, the motions being worked from gearing below. This is the most useful piece of hoisting gear for the yard.

Away from the yard, work is erected mostly by means of sheer legs. The sheer poles are arranged to suit the work. The tripod form is of little service, because it does not allow of adjustment over the work. Two poles, or one only, are most commonly used. If two poles are employed they are lashed at the top, and held with guy ropes or chains, which are tightened with knots or with pulley blocks, and securely fastened to any attachments that happen to be conveniently situated. A single pole is similarly secured. The poles should be well stepped into the ground. By means of the pulley blocks the guys can be either let out or shortened, in order to bring the tops of the poles directly over the work to be hoisted. The longer the poles, the greater their horizontal range.

The hoisting tackle employed with sheer-poles is of a varied character. Thus, for light loads, a single loose pulley hooked to the poles is used. For loads of a few hundredweights, too heavy to be lifted direct, a pair of

wooden blocks, single or double, and a rope are suspended from the poles, and there is then a rapid lift, with some gain in power. For loads of a ton and more, the differential pulley blocks, are employed as in the shops. For loads of several tons, a powerful pair of blocks, worked from a crab on the ground, are employed. The latter is usually a hand crab, with single and double gear, and sometimes with treble gear. There is thus power gained at the crab and on the blocks, and in this way, and with poles of sufficient strength, there is no practicable limit to the loads that can be lifted out of doors with sheer poles.

Other methods of hauling are also adopted. A derrick crane, when available, is more useful and quicker in action than the crabs and blocks. By means of the raising and lowering of its jib a considerable horizontal range of movement is obtainable. Derrick cranes are always to be had on hire or second hand, and they are quickly erected, and are saleable when done with. Both hand and steam derricks are used. For lifting or lowering heavy structures bodily, the jacks, both screw and hydraulic, are employed. Work is not only lifted and lowered, but is also traversed along bodily by means of jacks. These are the principal methods by which light and heavy work is lifted into position in shops and yards.

Examples of slings.—By far the commonest mode of lifting work is in a sling. The commonest form is shown in Fig. 283. It consists simply of a short length of endless rope or chain wrapped round the work which has to be lifted, passed once through the bight, and hooked up. The sling can be made more secure by passing the end round once more and through the bight thus formed (Fig. 284).

These slings are used on all kinds of work, for shafts,

cylinders, brackets, bed plates, wheels, rings, and all conceivable forms of castings and forgings. Fig. 285 illustrates the employment of two sling ropes, or alternatively chains, employed in lifting a bed plate too large to be embraced with a single sling. The top one, A, is simply passed through the bights of the lower one, B, and its bights are slipped into the crane hook C. The bottom one is spread

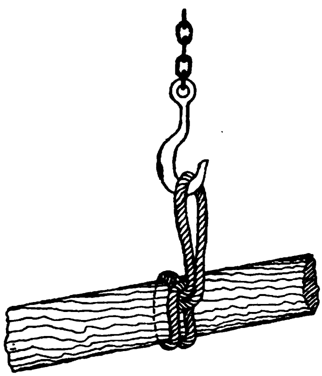


FIG. 283
Common Sling.

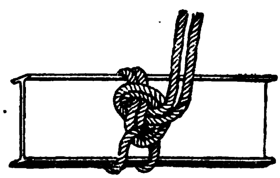


FIG. 284
Common Sling.

out to form a broad base underneath the casting, to prevent it from becoming tipped during lifting. In flat work, not too large to be embraced by a single sling, it might be lifted in A only, the two bights of A being slipped into the crane hook, instead of one end of the sling being slipped through the bight of the other end, as in Fig. 283. But then A in Fig. 285 would be more liable to slip than the sling in Fig. 283, because the latter tightens closely round the work.

Another form of sling, though not used for lifting, is shown in Fig. 286. It is used for a man to sit in when it

is inconvenient to erect staging. It is a modification of the bowline knot, which cannot slip.

A large quantity of slinging is done without the double chain or rope, but with single ropes. Thus, to haul up planks for staging, or poles, or beams, or shafts, a slip knot or running knot, Fig. 287, is used. What is termed an

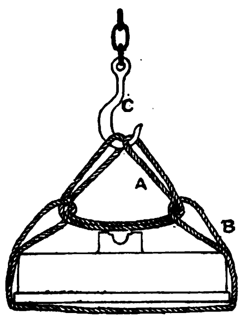


FIG. 285
The Use of Two
Sling Ropes.

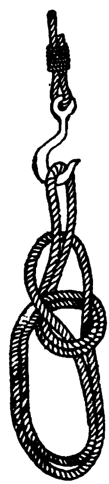


FIG. 286
Bowline Knot.

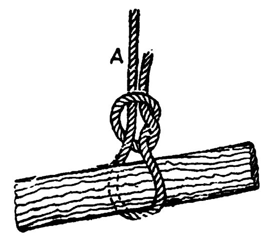


FIG. 287
Slip Knot.

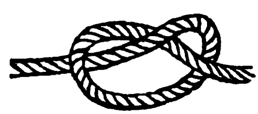


FIG. 288
Overhand Knot.

overhand knot, a knot which is in frequent use, shown separately in Fig 288, is first formed and the standing part A in Fig. 287 is then passed through the knot, to form a loop, and pulled taut. When a plank, or shaft, or piece of girder, or casting has to be lifted without being permitted to swing about, it is usual to duplicate the fastening near each end, or to form a series of overhand knots, Fig. 289, and so keep the plank or girder, as the case may be, steady by hauling at both ends. Thus Fig.

289 is called a *chain knot.* What is termed the *timber hitch* is shown in Fig. 290. The bight of the rope is brought round the timber, then round the standing part, and back round itself several times. It cannot slip; the tighter it is hauled the faster it holds, and the rope would

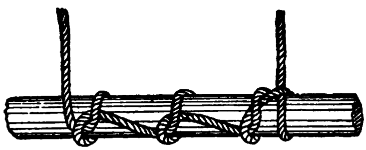


FIG. 289
Chain Knot.

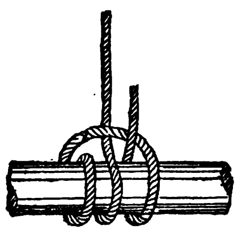


FIG. 291
Magnus Hitch.

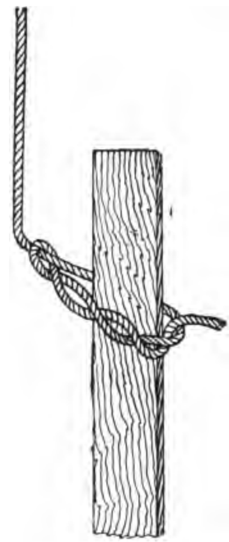


FIG. 290
Timber Hitch.

break before it would slip. Fig. 291 illustrates another method of securing a plank or piece of work. The rope is taken three times round the spar in the manner shown, and up through the last bight. This is termed a *Magnus hitch.*

Various other methods are employed for slinging different kinds of work. Some of these are shown in the succeeding illustrations.

Plates are lifted in various ways. Fig. 292 shows an unsafe method of lifting plain plates, a method which has sometimes caused serious accidents. The plate is pinched with a clamp A, and a sling chain passed round the clamp, or the hook B of the tackle inserted, and the plate lifted in this manner. But the clamp is apt to slip, and to let the plate fall; and in this way the element of danger

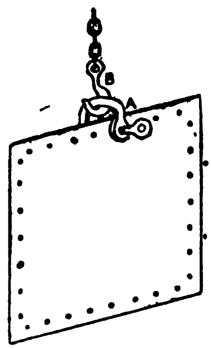


FIG. 292
Unsafe Method of Lifting a Plate.

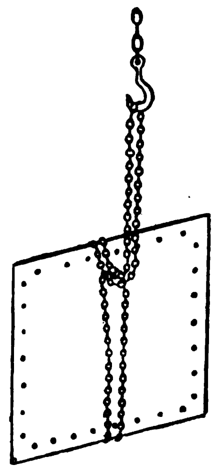


FIG. 293
Plate Lifted with Sling Chain.

comes in. If, however, the plate is flanged, as a tank plate, or if there is any set off against which the clamp will take a bearing, this is a quick and safe way. But when plates are quite plain, as in the case of rolled plates of wrought iron and steel, the sling chain should be passed round, as shown in Fig. 293, and this, if properly done, cannot slip. Another way in which a plate can be lifted is shown in Fig. 294. When plates have holes in them, a bar, A, can be passed through a hole, and a sling chain, B,

passed round each end of the bar, and the upper part slipped over the hook of the lifting tackle. These methods are only suitable for lifting plates edgewise. To lift them flatwise, other ways are selected. Chains having a ring at one end and a hook at the other are employed, Fig. 295, A. Frequently these chains are provided with a swivel, as at B.

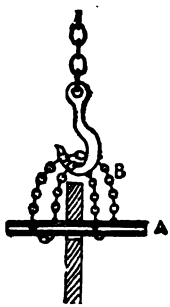


FIG. 294
Plate Lifted with
Sling around Bar.

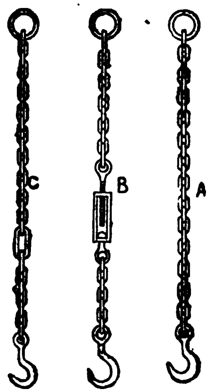


FIG. 295
Sling Chains.

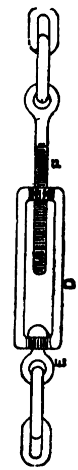


FIG. 296
Swivel.

The swivel is shown enlarged at Fig. 296. It consists of a looped portion, D, a swivel eye, E, and a screw, F, with an eye. Such swivels, slightly modified, are also used for putting screw tension upon framed work which has to be pulled together close previous to drilling and bolting, or riveting. Then when there are three or four such chains lifting, their lengths can be mutually adjusted with the screw of the swivel, until all alike pull taut. Frequently also there is a large link about the centre of the chain to

slip hook into, after the bight of the lower portion of the chain has been passed round the work, Fig. 295, C. Three or four such chains are used, their eyes are slung in the hook of the tackle, and the chain hooks are either passed underneath the work or through eye bolts—methods being chosen best adapted to any given piece of work. The commonest method is to slip the hooks beneath the edges of the work, or into holes, if such are available. In Fig. 297, eye bolts, A, are passed through holes conveniently

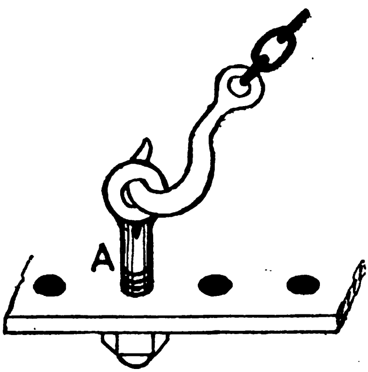


FIG. 297
Lifting Plate with Hooks and Bolts.

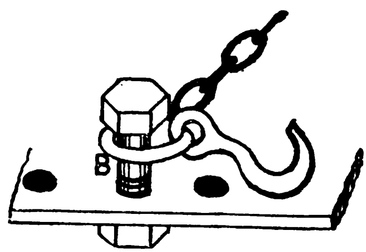


FIG. 298
Lifting Plate with Rings and Bolts.

situated, and the small hooks of the sling chains are passed through them. If eye bolts do not happen to be handy, another practice is to substitute a common bolt, Fig. 298, for the eye bolt, and before putting the nut on, slip the bolt through the shutting link B of the chain, and so carry the weight. A general view of a plate which is being lifted in this manner is shown in Fig. 299. Rings and plates are also lifted horizontally by rigid rods hooked at the end, by the methods illustrated in Figs. 300–1. Fig. 300 shows a rod divided into two at about the middle

of its length, and the lower ends are set off at right angles to pass underneath the work. In Fig. 301 each rod is

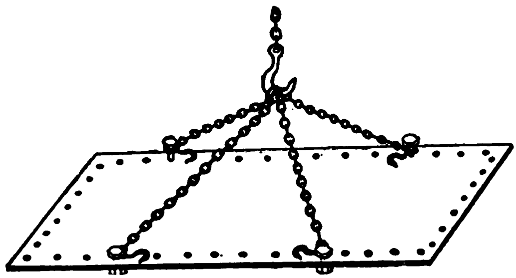


FIG. 299
Lifting Plate with Rings and Bolts.

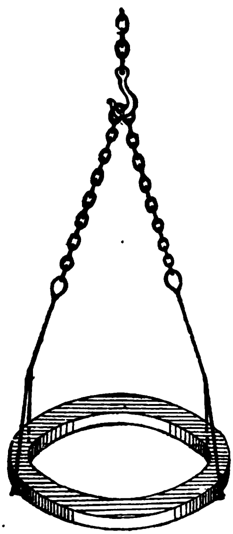


FIG. 300
Lifting Ring with Hooks.

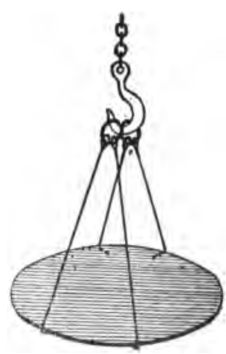


FIG. 301
Lifting Plate with Hooks.

separate from the other, and is attached with an eye to a ring, one pair of rods to a ring. The rings are slipped over

the hook of the hoisting tackle, and the lower ends of the rods are bent round at a right angle.

A method of lifting a light shaft or other piece of work

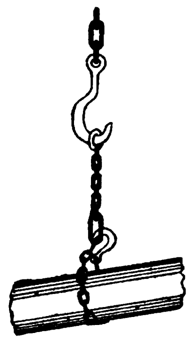


FIG. 302
Lifting Shaft with Hook in Link.

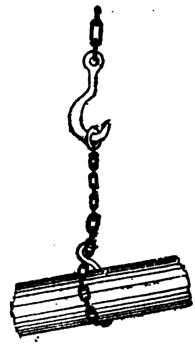


FIG. 303
Lifting Shaft with Hook round Bight.

FIG. 304
Single Blackwall hitch.

FIG. 305
Double Blackwall hitch.

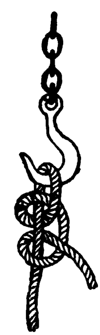


FIG. 306
Sailor's Knot.

is shown in Fig. 302. It simply consists in lapping the hooked chain round once, and slipping the point of the hook into the enlarged chain link, Fig. 295, C. If the point of the chain is, however, too large to enter the link,

then it can be slipped round a bight of the chain (Fig. 303).

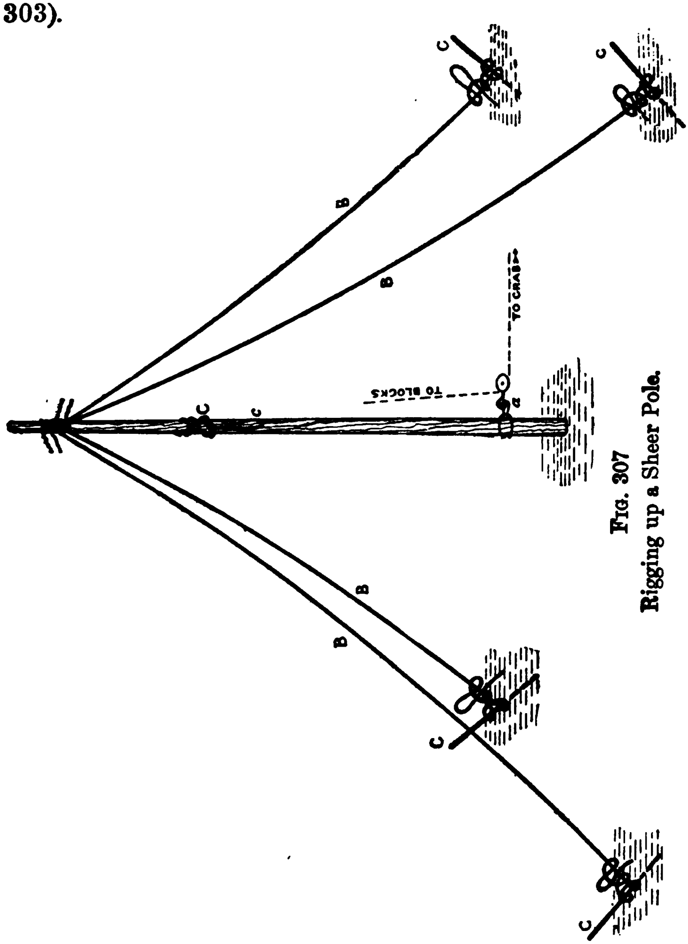


FIG. 307
Rigging up a Sheer Pole.

Some of the methods of attaching single ropes to crane hooks, and of forming eyes, are shown in succeeding figures. Fig. 304 is a *single Blackwall hitch.* It is formed

of a single bight, and as the standing part A jams B against the hook, it holds moderately well for a temporary purpose. But there is better security in the *double* Blackwall hitch, Fig. 305, which cannot slip, especially if the end is lashed to the standing part as shown. Fig. 306 shows a sailor's knot, formed of two half hitches taken round the standing part. It is quickly made, and cannot slip.

Lashings.—Fig. 307 illustrates the method of rigging up

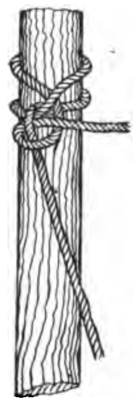


FIG. 308
Lashing for Guy Rope at Top of Pole.

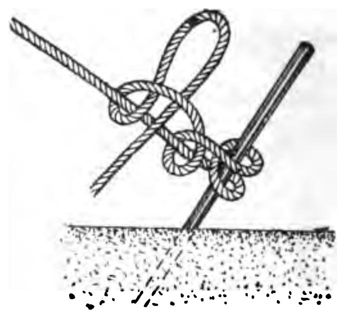


FIG. 309
Lashing for Guy Rope around Peg.

a single sheer pole, with four guys, B, and sling, C, for pulley blocks. The fastenings are shown enlarged in Figs. 308, 309, 310. Fig. 308 shows the lashing for a single guy at the top of the sheer pole; Fig. 309, the lashing to the peg or other attachment in the ground. The latter can be cast off quickly by taking out the loop. Fig. 310 shows the sling for the pulley blocks upon the pole.

These single sheer poles are largely used for lifting columns, girders, and work of not very broad area. They

are erected vertically by means of ropes, or of a winch. But considerable inclination can be imparted to them with perfect safety by slackening out the guys upon one side and shortening those on the side opposite. Without much trouble they can also be shifted along to come over

FIG. 310
Sling for Pulley Blocks.

FIG. 311
Lashing of Two Poles.

work removed a few feet or yards apart. Unless the distance is considerable, it is usual to prise the pole along at the bottom, and slacken and tighten the guys at the same time. Although stakes C are shown in the figure, other attachments which may happen to be available are as often made use of—as beams, trees, columns, portions of buildings, etc.

For very much work of large area, however, a single sheer pole is not so convenient as a couple of poles lashed together at the top, and spread out at the bottom. The mode of lashing them is illustrated in Fig. 311. The two poles are first laid together parallel; the rope is then bound round the two several times, carried between the poles and round the lashing, and knotted as shown with a reef knot. This mode of lashing is also termed a *Portuguese knot.* Opening the legs at the bottom tightens the fastening. Work of large area can be lifted between the poles, and they can also be leaned over out of the perpendicular, being supported by the guys. Gin sheers consist of three poles in tripod fashion. They are not so convenient for erecting engineers' work as those already named.

FIG. 312
Mode of
Lashing Spars.

It sometimes happens that the sheer poles are not long enough for hoisting some portions of work. Then a couple of poles are lashed together with rope, three or four lashings being employed in a length of perhaps 6 ft. or 8 ft. Fig. 312 illustrates one method of lashing out of several. An end is laid parallel with the spars, and the rope bound round and pulled taut. Then a few loose turns are taken, and the other, or free, end passed backwards under them; the loose turns are then tightened and the two ends pulled taut. For more secure fixing, wedges of wood are often driven in between the rope and the spar, the wedges entering into the hollow between the spars.

Hoisting.—Referring to Fig. 307, there are two ways in which work is hoisted by means of poles. Light work is

lifted by means of common pulley blocks of various powers, slung from the lower bight *c* of C. Heavy work is lifted by means of a crab, situated a little away from the sheer legs, but having its chain brought along horizontally to a

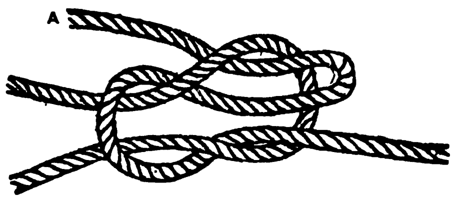


FIG. 313
Draw Knot.

pulley, which is fastened to the pole with a common sling *a* or other means. The direction of motion of the chain is thus changed to the vertical.

Rope fastenings.—Frequently, in the work of hoisting, the ends of ropes have to be fastened together. Succeeding

FIG. 314
Reef Knot.

FIG. 315
Granny Knot.

figures illustrate a few of the methods which are made use of. When ropes have to be fastened, but cast loose quickly, the *draw knot* in Fig. 313 is employed. This is perfectly secure; but on pulling out the end A the knot can be loosened, and the ropes cast off immediately. Fig. 314 is a *reef knot*, very common, and also entirely

secure. Fig. 315 is shown in contrast. This is a *false* or *granny knot*, and ropes fastened thus run risk of becoming drawn apart by tension. Figs. 316 and 317 are *sheet*

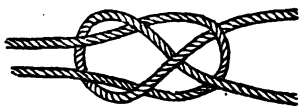


FIG. 316
Sheet Bend.

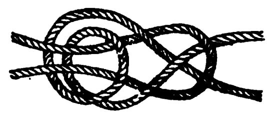


FIG. 317
Sheet Bend.

bends—the first single, the second double—and are both useful. A rope is shortened without cutting by sheep shanking. Fig. 318 is a *sheep shank*. Two bights are formed in the rope, and a half hitch is made at each end

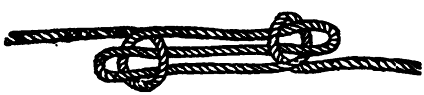


FIG. 318
Sheep Shank.

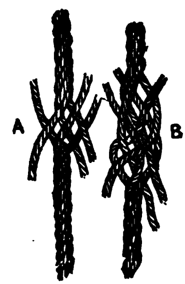


FIG. 319
Splicing.

and slipped over the bights. There are several other methods of shortening ropes, but this is the simplest.

Splicing.—Jobbing fitters and men who are sent out to erect work should know how to splice ropes—a useful acquisition at any time, but especially so when the ropes of travellers and of hoisting gear require to be connected up or to be lengthened or shortened. Fig. 319 illustrates what is termed the *short splice*. This is made use of in

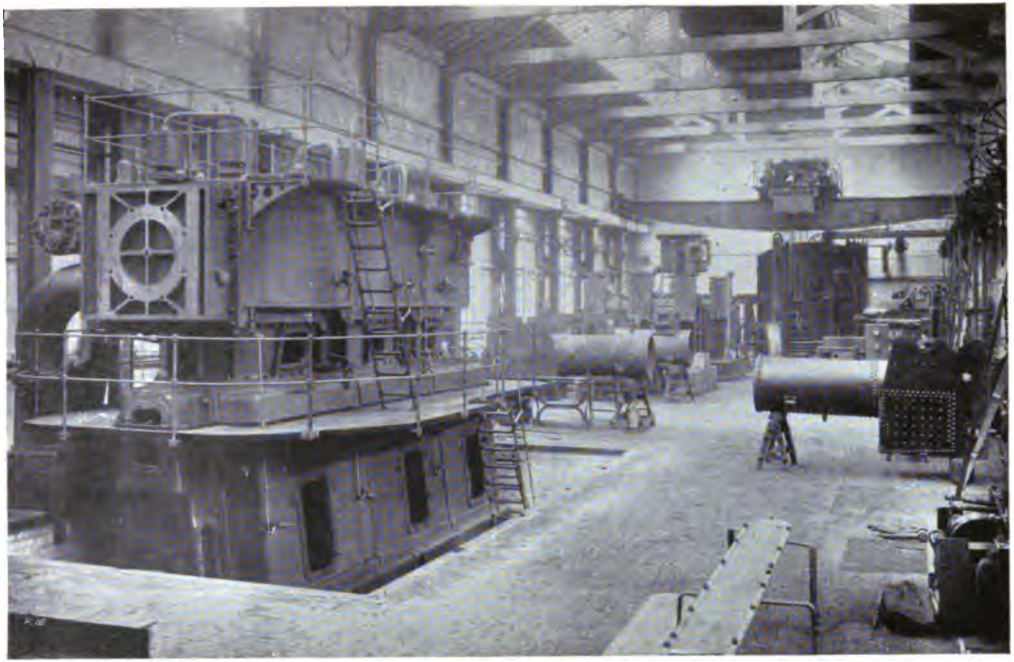


PLATE 7.—Shop of J. and H. Maclaren, Leeds.

[Facing p. 336.

work where a little bulge in the rope at the point of jointure is of no consequence, and is effected in the following manner:—The strands are unwound for a length of from 6 in. to 12 in., according to the size of the rope, and *married* or *crutched* together in alternate positions, shown at A, and thrust close together. Then the separate strands are passed over and under the other strands alternately several times in succession in the manner partly shown at B, where the process of splicing has been commenced, and the strands are all loose, the better to show their relative positions. As the work proceeds, the rope is not unlaid any more, but the strands are thrust asunder with a marlingspike, Fig. 320, sufficiently to permit of the entrance of the strands, which is further facilitated by well greasing the strands. After the entry of each strand it is pulled taut. The ends of both ropes are treated in exactly similar fashion, each alike being worked between the strands of the other. To reduce the bunch at the spliced portion, the rope is rolled between boards, or under foot.

The *long splice* is used for cotton ropes running at high speeds over pulleys. The advantage of the long splice is, that enlargement of the ropes is prevented, because the splice is carried over a length of from 6 ft. to 12 ft. It is almost impossible to illustrate this properly—or, indeed, any splicing—by means of diagrams; but a general idea of the method can be obtained from Figs. 321 and 322. The ropes to be united are first unlaid for a length of several feet, and the ends placed together with the strands in the same relative position as in the short splice. Then a strand is unlaid, and the space left thereby filled up with the corresponding strand from the other rope. The appearance of this unlaying and filling in is shown in Fig.

321, where A is the strand unlaid, and B the strand which is taking its place. This is repeated with two more strands

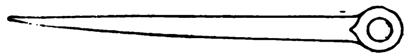


FIG. 320
Marlingspike.

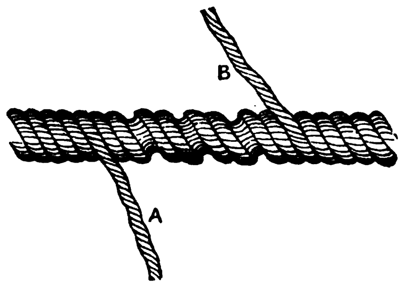


FIG. 321
Long Splice.

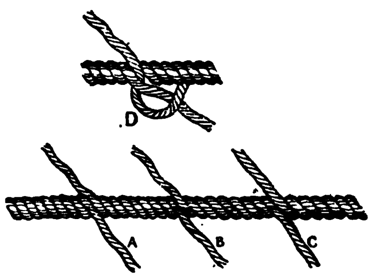


FIG. 322
Long Splice.

at the further end of the splice, and two more about the centre. Fig. 322 illustrates a three-stranded rope at this stage. Overhand knots, D, are made with each, and the ends of the strands finally spliced by working them between

their fellows. Before cutting off the ends the rope should be stretched.

Fig. 323 shows an *eye splice* begun. It is made like an ordinary short splice, so that the ends shown in the figure, there passed once between their strands, have to be worked under and over the strands four or five times. These eyes are often required for permanent use on hoisting tackle, and frequently inclose iron rings for durability. Similar methods are employed for uniting wire ropes, but the length of splice is greater.

FIG. 323
Eye Splice.

Jacking.—Superstructural work of not too large area can be safely lifted about with sling chains, provided care is taken so to arrange the chains that there shall be no twisting or undue stress put upon any one portion or portions of the structure tending to distort or wind it. In this way base plates, with all or most of their attachments of standards, gearing, and shafts, portions of engine work, etc., can be lifted safely for the purpose of being deposited in their proper positions upon their fellow portions of work. But very bulky work, or work of large area, cannot be lifted in this way, and must instead be jacked up, or jacked along or lowered by jacks, as may be required.

There is little to be said on the subject of jacking. The action of jacks is necessarily only very slow; but, on the other hand, there is scarcely a practical limit to the loads that may be moved thus, or to the range of movement possible. Though the range of operations of a jack is limited to a few inches—about 11 in. or 12 in.—yet loads are jacked through several feet by the introduction of suitable blocking, care being tåken to give a sufficiently broad base to

the blocking or packing, for security. The higher the range of lift, the broader must be the base. The packing introducéd in any case consists of deals or balks of timber. When the load has been lifted a few inches, fresh packing is introduced, and when the vertical range of the jack is reached, the jack itself is blocked up, and the lifting is proceeded with at the new level. During jacking the elevation of the work should proceed evenly and regularly at each corner; otherwise it will become twisted and winding, and bending or fracture of parts may occur. The lowering of massive work by means of jacks proceeds on similar lines as its elevation; only that, instead of blocking being inserted, it is removed piecemeal. The jacking of work along the ground or on rails is done by driving a piece of angle iron or bar into the ground, and making that a point of resistance for the horizontal or slightly diagonal thrust of the jack, or by taking advantage of any rigidly fixed mass that happens to be conveniently situated for the purpose. Besides this, there are special horizontal and pulling jacks constructed.

Many jacks lift upon the head only. The most useful are those which lift at both head and foot, the latter being useful for insertion in places where there is not room to insert the head. Roughly, the powers of jacks are as follows:—A jack with a $2\frac{1}{4}$ in. screw will lift 8 tons, one with a $2\frac{3}{8}$ in. screw 10 tons, with a $2\frac{1}{2}$ in. screw 15 tons, with a $2\frac{3}{4}$ in. screw 18 tons, and with a 3 in. screw 20 tons. Hydraulic jacks will lift to 50 and 60 tons, and some special ship jacks as high as 150 and 200 tons.

I need not describe any of these jacks in detail, as their forms are pretty well known. But some special forms seem worth notice. Fig. 324 is a type used specially for adjusting horizontal shafts and axles against the centres of their

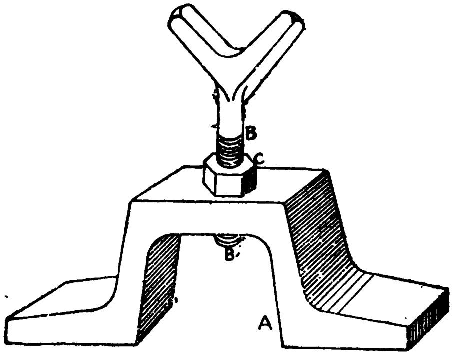


Fig. 324
Adjustable Vee Carrier or Jack.

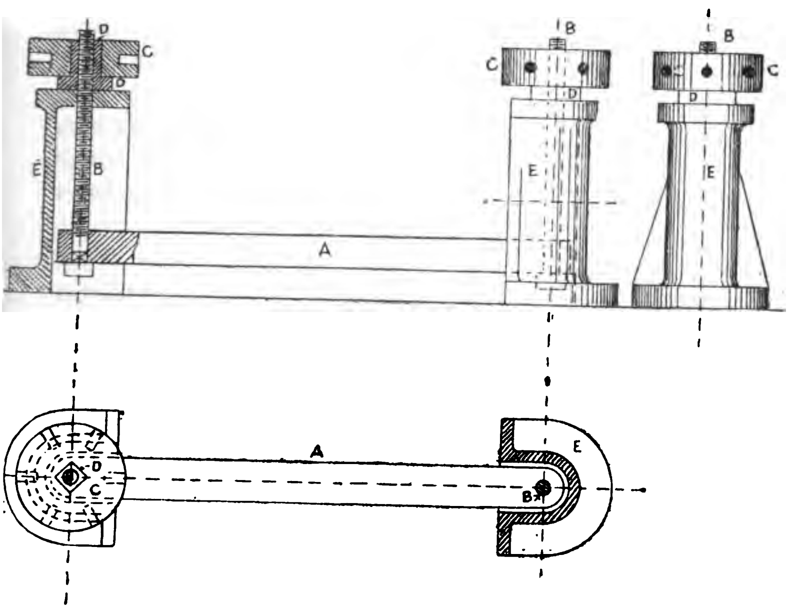


Fig. 325
Double Jack.

wheels in readiness to be pulled on by screw or hydraulic pressure. It consists of a casting, A, and a screw, B, the latter furnished with a hollow forked end for the support of the shaft or axle. The screw, with its fork, is elevated and depressed by means of the nut C.

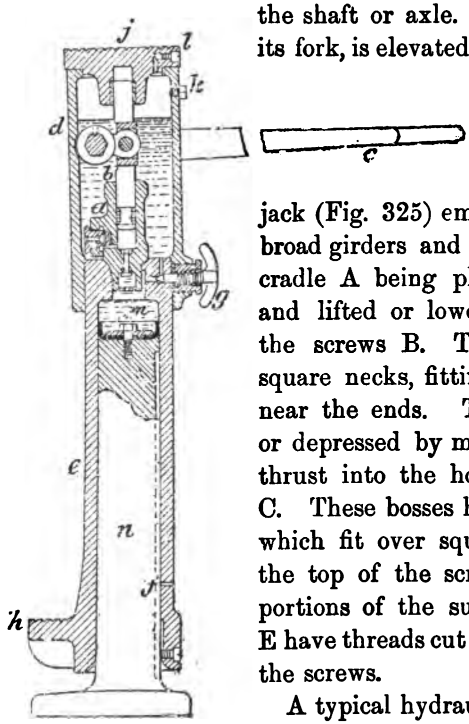


FIG. 326
Hydraulic Jack.

The second form is a double jack (Fig. 325) employed for lifting broad girders and frames, the bar or cradle A being placed underneath, and lifted or lowered by means of the screws B. These screws have square necks, fitting into the bar A near the ends. They are elevated or depressed by means of iron bars thrust into the holes in the bosses C. These bosses have square holes which fit over square necks, D, at the top of the screws. The upper portions of the supporting castings E have threads cut in them to receive the screws.

A typical hydraulic jack, made by Tangyes Ltd. of Birmingham, is shown in Fig. 326. The operating mechanism includes a pump *a* with a plunger *b*, which is moved up and down by the lever *c*. The water is contained in the chamber or head *d*, mounted on the cylinder *e*. Pumping continues until the small outlet hole *f* gets as high as the chamber *m*, after which the water runs out through *f*. When it

is desired to lower, the screw *g* is slacked back slightly. Loads can be lifted with the claw or foot *h*, but they should not exceed about one quarter of the total capacity of the machine. The head *j* is cross hatched, like the foot *h*, to prevent skidding; *k* is the charging hole, closed by a screw, and *l* is an outlet for air when the chamber *d* is being filled. The water in the space *m* is prevented from passing the ram *n* by a packing leather, shown black.

CHAPTER XV

REPAIRS

TAKING mechanisms apart for repairs is often one of the most troublesome jobs a fitter can be put to do. Between corrosion, dirt, distortion, and perhaps fractures, it is a case of steering between Scylla and Charybdis. Often, too, the machine which has to be taken apart and repaired is one with which the fitter has had little or no experience, and then he has to feel his way, or he may find after it has been taken apart that putting it together again is like putting an intricate puzzle together.

Before commencing to take any mechanism apart it should be thoroughly looked over, in order to gain a clear idea of the general arrangement and location of parts. In most cases it will be necessary to mark similar parts by stamping, or with a centre punch. Machines with few parts, or parts whose relations are quite obvious, do not require to be marked at all. But this is not the case with those whose sections and details are numerous, and similar in size and in appearance. The practice then is to mark either with centre-pops, or with letter stamps or figures, similar marks being put upon adjoining parts, as brasses and their blocks and caps, glands and their stuffing-boxes, etc. A large number of similar parts can be marked with centre-pops, not only by increasing the number of pops, but by also arranging them in devices, Fig. 327, and many

others. When letter or figure stamps are used, the combinations of double letters, or of letters with figures, give plenty of distinctive marks, after the single letters or figures have been used up. The marks should not be put upon working faces, but upon those where there is no frictional contact, and generally on parts which are more or less hidden when the mechanism is put together.

A very little often suffices to make all the difference between the free working or otherwise of a motor or

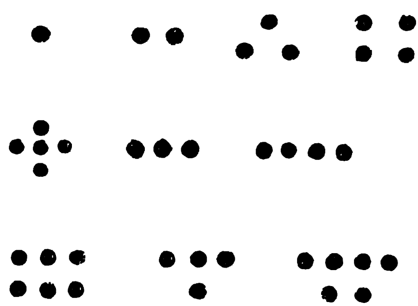


FIG. 327
Centre-Pops.

mechanism. Instead of taking apart at random, it is therefore wise to thoroughly overhaul everything in leisurely detail, look all round and into it, try what parts are slack and worn, where escape of steam or liquid is taking place, what portions are bent or fractured, and so forth. Without such careful forethought and leisurely examination, it may happen that a lot of needless so-called repair work will be done without touching the main evils which require attention.

The separation of parts.—This is often a matter of so great difficulty, owing to rust, the effects of heat, acids, and pitting, formed by acidulated water and bad lubricants,

that fracture of some, and bending of other portions is sometimes almost unavoidable. When studs, screws, pins, and faced joints have been in their places unmoved for many years, there is usually a great deal of corrosion present, especially in structures which have been largely exposed to weather; and in such it becomes a task of extreme difficulty to get them apart without damage. A copious supply of oil, especially benzoline, aids the removal of rusted parts, time being allowed for the oil to run between the surfaces. Blows should be generally avoided, as they are apt to cause fracture of studs and screws. Though gentle tapping will often start a joint, leverage only, or chiefly, should be employed. Sometimes, however, judiciously-administered blows are necessary to start a joint.

To remove studs, use a nut and a lock nut. Or, if they have to be replaced with new ones, sometimes a square is filed on the end to receive a tap wrench, with which they are turned out. Keys must be got out by driving; wheels must be got off their axles, either by driving the axles out or preferably, by exercising screw or hydraulic pressure. When studs, screwed stays, and screws happen to break off, they must be drilled out and the holes retapped. Rivets are cut out by first shearing the heads off, and then by driving the shanks out. The tool used for cutting off the heads is shown in Fig. 328, one man holding the tool in the manner shown, while the helper strikes it with a sledge. After the head has been shorn off thus, the rivet is driven out with an ordinary punch, handled with withy handles.

Renewals.—In the work of repairs it becomes a question for consideration to what extent parts shall be made new, and to what extent patched up. Frequently, when time is an object, both methods are of necessity adopted, tem-

porary patching being done until new parts can be made. Generally, the question of what repairs are necessary, and how best to effect them, is one that calls for the exercise of much judgment. The line has to be drawn between efficiency and economy. It is not wise to make a multitude of parts new, so running up expense; nor is it judicious to patch up over-much for the sake of economy, involving the going through the work again at an early date. Let us take a few practical examples by way of illustration.

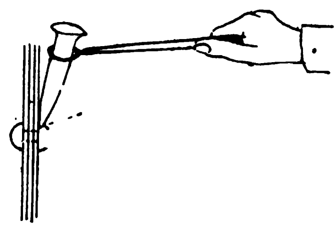


Fig. 328
Cutting off Rivet Heads.

Examples.—In the first place, as to what repairs are most likely to be required:—In engines, pumps, and machines generally the sliding surfaces become worn and scored. These include slippers, rods, journals, and brasses, glands, valves, and valve faces; pistons, and cylinder bores, rods also become bent, pins wear loose, and fittings in general slack. As each portion of a mechanism is being removed, note all matters that should be corrected. In an engine, remove the steam-chest cover, and observe the setting of the valves at their extreme positions. Perhaps lap and lead may be unequal, or too great or too little in amount for the class of engine, due either to original bad setting, or to alteration due to wear of parts. Some of the older engines show terribly bad results in this respect, being fitted at a time when the importance of proportional lap and lead were not so well understood as they are now. Such resetting of the eccentrics, or alteration in the lengths of rods, or taking up of slack as may be neces-

sary for proper resetting of the valves, if noted before pulling the engine apart, can be effected before putting it together again. If link-reversing gear is employed, its action should also be observed, as, for instance, whether it produces approximately equal amounts of lap in backward and forward gear, and whether the valve rod answers immediately to the action of the reversing lever. Probably it will not, in which case the cause will have to be sought in slack fitting pins, or die block, or in too great elasticity of some parts. New pins may then have to be fitted and ground in, or a new die block, and perhaps wearing parts may have to be newly case-hardened. If the eccentric or eccentrics have to be reset slightly, the alteration may be effected by filing the key-way longer to one side, and inserting a new key, a very little alteration being sufficient to increase or diminish the throw.

A frequent cause of faulty working of an engine is the fracture, or the excessive wear of piston rings. This is seen at once on taking out the piston. It is useless to try and run with such rings: the only way is to insert new ones. Another, the most common cause of faulty working is the wearing and scoring of faces of all kinds, both flat and circular; slide-valve faces, rods, and the bores of cylinder, glands, journals, and the bearings. When the valve faces of cylinders and slide valves are worn and scored badly, it is usually necessary to replane and scrape them. The valves of gas engines are usually only scraped. In the case of slide-valve faces of steam engines, a new valve is frequently necessary, thickened up on the face, to compensate for the wear of the face in the steam chest. Sometimes a liner is put upon the face in the cylinder. Then the liner has the ports cut in it and is fastened with studs riveted over in countersunk holes.

Cylinders frequently wear badly in the bore, not only becoming elliptical, but also larger at one end than the other. In such a case, reboring is the only remedy. Only the smallest amount actually necessary is taken out—one light roughing cut, and one fine broad cut. This necessitates a new piston, as well as new rings.

When rods are scored lengthwise, the only course is to turn them down and make new glands, or else bush the existing glands with gun metal. If new glands are made, the old ones can be used as patterns by filling up the holes with core prints, giving due allowance for boring, and wrapping lead around the outside to allow for turning. When journals are worn and scored, they should be turned down, and new brasses made. Usually with proper lubrication, the journals are scarcely worn at all; but the brasses wear. If the wear is but slight, the brasses are packed up with liners. Sometimes, when practicable, the relative positions of the top and bottom brasses are reversed, and the joints filed to close them up again, it frequently happening that one wears more rapidly than the other, according to the direction of maximum stress or pressure on the shaft. When brasses are much worn, they must be replaced with new ones. The new ones are often cast from the worn ones, the worn portions being lined up with lead for moulding to allow for boring and facing.

Shafts and spindles frequently become bent, more or less, by undue stress. They should be straightened with a hammer of lead or copper upon a block of hard wood. To test the truth of their correction, they should be run round between lathe or planer centres, and the projecting portions marked with chalk previous to removal for further correction.

When circular faces have become worn, such faces, for example, as those between the collars on shafts and spindles and their brasses, the expense of new brasses or new shafts is frequently saved by inserting washers of gun metal or wrought iron of suitable thickness between the worn faces. Or new collars may be shrunk or welded on.

Lift valves and cocks with annular faces are reground with sharp sand and water. The valves are not completely revolved upon their seatings, but only turned through portions of a circle by hand. A little grinding usually suffices, because the wear is seldom great, and a little alteration effects the difference between leakage and tightness. A convenient method of turning a small valve is illustrated in Fig. 329. A fitter's screwdriver, A, employed for turning in stove screws is used, and a slot is sawn in the valve stem B to receive the screwdriver. By these means the valve is rotated to right and left in its seat C alternately.

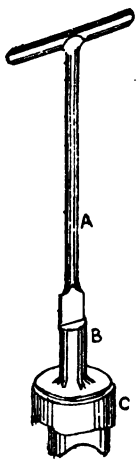


FIG. 329
Grinding-in Cocks.

Broken parts of cast iron are frequently mended by patching with wrought iron, and a good, even though rather unsightly, job made thereby. Rivets or studs are generally used; if the latter, they are riveted over in countersunk holes. If the broken or cracked part has to hold liquid, then it is caulked before patching, with iron borings or filings and sal-ammoniac, in water. When small corners are broken off castings, it is sometimes the practice to burn new corners on—that is, molten iron or gun metal, as the case may be, is poured with proper precautions over the fractured surface, until union takes

place by the fusion of the surfaces. All superfluous metal is removed afterwards, either by machining or grinding. This practice has but a limited application, and cannot compare with the facility or certainty with which broken or damaged parts in wrought iron can be welded.

For temporary purposes gear wheels are frequently repaired in two ways. In one method pins of wrought iron or gun metal are tapped into the rim, and are filed to continue the outline of the broken tooth (Fig. 330).

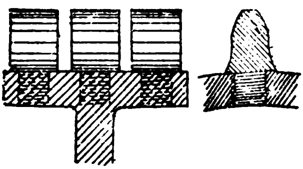


FIG. 330
Repairing Broken Teeth.

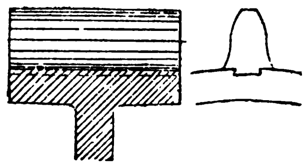


FIG. 331
Repairing Broken Teeth.

In another, new teeth of wrought iron are fitted in with dovetails (Fig. 331). If done properly, wheels so repaired will often wear for an indefinite time—often for many years, especially for gears subject to little stress and shock, such as the wheels of lathes, and shop mechanisms generally. For heavy work, the method is not suitable, except for an emergency, as while a new wheel is being prepared.

When a motor or mechanism is repaired, it is always worth the while at the same time to effect such polish as can be done with comparatively little trouble. A little grinding off of rust upon the emery wheel, rubbing off of dirt with emery cloth, cleaning up of iron and brass effects a vast improvement in appearance, and is well worth the slight trouble involved.

Replacing broken gear wheels.—At various times fitters

working out of doors have to take dimensions of worn or broken wheels, from which to have new ones made to gear with existing ones in position. There are a good many points of importance to be attended to in such work, as the following illustrations will indicate. The fitter has to take dimensions, and draw out the new wheel, or to take dimensions for entirely new wheels required to effect changes in direction of motion, or in rates of revolution. Sometimes dimensions are given, but it is seldom safe to attempt to work from dimensions supplied by people who are not engineers. Often the diameter is given, and number of teeth, but without anything to indicate whether the diameter is at pitch circle, or outside the points of the teeth. Particulars are seldom given of dimensions and shapes of teeth, or of depth of boss, or minor details. So that it is generally safer to send a trustworthy man to take particulars of wheels that cannot be brought to the works.

It is generally well to take a plumb bob or a plumb rule, a lath or two, a bradawl, screwdriver, and half-a-dozen screws, a rule, and calipers. With these, any particulars can be taken of spurs or bevels.

Spur gears.—If dimensions have to be taken of a spur wheel in place, and a replace wheel has to be made without any further reference to the worn one, no forethought should be lacking. A man looks foolish when he comes back to shop, and finds that he has forgotten some particulars without which the new wheel cannot be made. There are the major dimensions to be attended to first. Count the teeth, and count twice, chalking the one you start from. Take the diàmeters to the points of the teeth, and also to their roots. If the shaft is small these may be measured right across on a strip. But if the shaft is

of moderate or large diameter this cannot be done. Then measure, still with the strip from the shaft to the teeth points, and roots. One end of the strip will be set against the shaft, and the radius of the latter added to get the correct radius of the wheel. Or, hang two plumb lines suspended by nuts, or anything heavy to hand, from the diameter of the wheel at the tooth points (see Fig. 337, p. 359), and measure and mark off the distance between them on the strip.

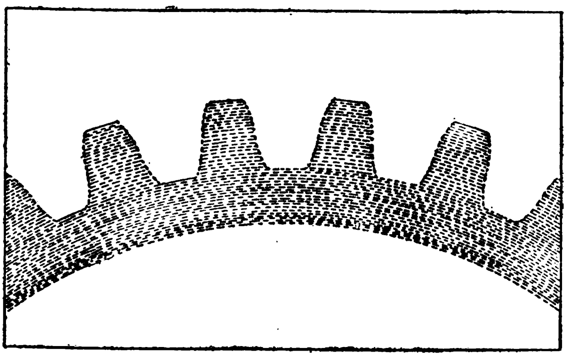


FIG. 332
A Rubbing.

The shapes of the teeth from which to make the new wheel, or from which to get those of the new wheel, in which the old one will have to gear, will be taken by means of a *rubbing*. That is, a sheet of white paper is taken, Fig. 332, long enough to cover about half-a-dozen teeth, and being laid against one face of the wheel, the fingers are rubbed hard against the paper, over the ends, and round the edges of the teeth. This leaves a good impression of the teeth forms on the paper, of which Fig. 332 gives an imitation. If a sharp outline cannot be obtained

thus, in consequence of the tooth faces being very bad, then a wooden templet is fitted between a few teeth, Fig. 333. In either case, having the tooth forms, they are drawn out upon a board on returning to the shop, and the pitch circle and the tooth curves located therefrom.

Measurements must now be taken of the boss and bore, the arms, and any other particulars needed. The shaft may be measured with calipers for the core prints, but for the boring of the wheel a gauge must be filed. A

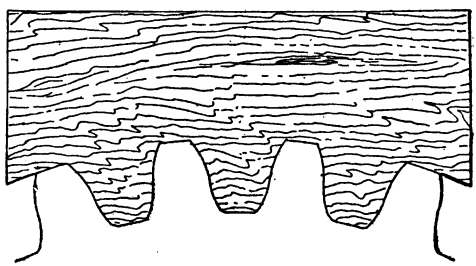


FIG. 333
Tooth Templet.

gauge should be also filed for the key-way. Sketches of the arms must be made, and fully dimensioned.

An awkward job sometimes is the taking dimensions from a broken wheel, when, as is sometimes the case, it has been smashed to pieces, and probably some of the pieces are not available. The only course open, then, is to see that all broken parts are brought closely together before attempting to take dimensions, assuming nothing, and checking everything.

If, instead of making a new wheel to replace an old one, a new one has to be made to gear with one already existing, then the centres must be taken from the shaft on

which the new wheel has to go to the teeth of the wheel with which it has to engage. These are best taken by measurement from the outside of the shaft to both root and point of the existing wheel. Then, having the diameter of the shaft and a rubbing of the teeth of the wheel, the rest can be worked out in the shop.

If the teeth of a wheel are worn very badly, the proper shape for the new one can generally be obtained from the less worn side—one side, as a rule, being merely smoothed by wear, while the other is deeply indented. The thickness at the root is generally intact, while the thickness measured on pitch line can be obtained from the pitch. If, however, the wheel is to gear with a mortise wheel, it is well to measure the thickness of the teeth of the latter for which, if worn, it will be desirable to make the iron teeth a little thicker than the rules give, to avoid backlash.

To get fairly good shapes of the teeth, centres will have to be located from which to strike the curves. The teeth will certainly not be all alike, and so an average will have to be struck. It is always safer to give the fullest rounding off to the points which they seem to warrant, in order to avoid possible interference of these when engaging with the roots of the other wheel.

When a wheel has to be made with teeth to gear with an existing wheel, the rubbing, or the wooden templet (Figs. 332, 333), is used to obtain the correct curves from, before those for the new wheel can be determined. If a wooden templet is used, then the tooth shapes can be scribed off on a drawing-board. If a paper rubbing is used, the tooth shapes can be pricked through the board, or the paper itself can be glued or pinned on the board. Then the centre of the wheel is obtained, and the position of the pitch line determined and struck, together with

curves for the points and roots. Afterwards the sizes of the generating circles which have been used for points

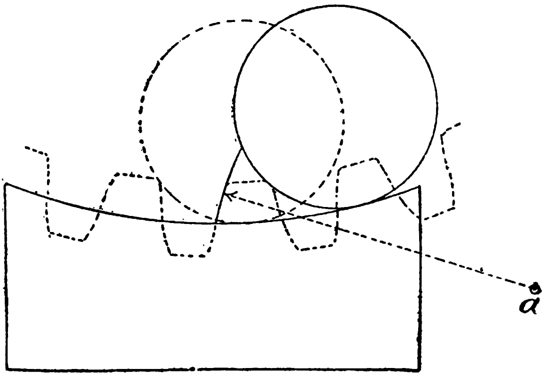


FIG. 334

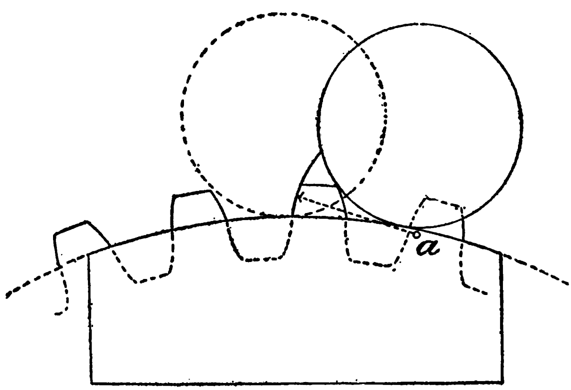


FIG. 335
Obtaining Generating Circles of Cycloidal Teeth.

and roots must be discovered. This is done by cutting templets to the curve of the pitch circle, and rolling generating circles of different diameters upon them until

the one is obtained which traces the curve. This will often be found to be one having a diameter equal to that of the radius of a small pinion of the same pitch; but in many old wheels, the teeth of which were originally struck without much regard to system, curious results may be expected. When the circle is found, which, when rolled on the pitch diameter, will trace the curve of the tooth—say, below pitch line, Fig. 334—that will then be used to strike the curves above pitch line of the wheel to gear with it, Fig. 335.

It will not do to assume that the same circle will strike the curves also of the pinion teeth above pitch line. It would, provided the original wheel had been struck out on a proper system; but this must be tested by making a sweep for Fig. 334, against which generating circles will have to be rolled to find the curves of the teeth below pitch line, and then this circle will strike those of the teeth above pitch line in the new wheel. The other curves will then have to be found similarly. The rest of the work is merely locating centres, as in Figs. 334, 335, from which to strike the curves so determined in a manner which is well understood.

If the wheel is an involute, only one curve is required, as shown in *a*, Fig. 336, by which the base line is obtained. A templet is made to the assumed base line, and straight-edge moved round it from the position shown in dotted lines to that in full lines. If a mark on the edge of the straight-edge, or a needle point is found to coincide with the outline of the tooth, the assumed base line is correct. But if not, another templet will have to be cut to a larger or smaller radius.

Bevel gears.—If the new wheel is to be a bevel, even more care is necessary than for a spur, because little

inaccuracies in wheels of this class, especially when the breadth of face is considerable, soon result in bad gear.

In addition to the trouble of obtaining properly formed teeth, the correctness of the bevel is important. It is very easy to get this slightly out of truth, and when that happens, bad gear is unavoidable. There is no chance to put bevel wheels farther into or out of action as in spurs, because one end of the teeth is held in check by the other. At the small end, an inaccuracy amounting to $\frac{1}{16}$ in. will be quite sufficient in many wheels to give trouble. In narrow-faced wheels there is little to contend with; but as width increases, the greater must be the care exercised. The bevel should be both measured, and checked by other means, and special care must be taken in preparing pattern parts to guard against error on the part of the moulder. The insistence on the necessity for all these checks may seem trivial to those who have had nothing to do with making new bevel wheels to replace old ones, or to gear with old ones; but they are fully warranted and emphasized by experience of good and bad work.

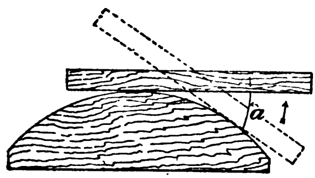


FIG. 336
Obtaining Base Line of Involute Teeth.

If a new wheel is to be made to replace an old one yet at work, dimensions taken in the following manner will afford a check on one another in drawing out the wheel in the shop :—Diameters are taken at the tooth points, on the largest and smallest ends. This can be done in the way previously described as suitable for the measurement of spur wheels, either by strips laid across the diameter of the shaft, if the latter is so small as to offer no inter-

ference to this method of measurement; or by measuring the radius from the shaft to the tooth points and roots. If neither of these is available, correct dimensions can be obtained by hanging two plumb lines, as in Fig. 337, and

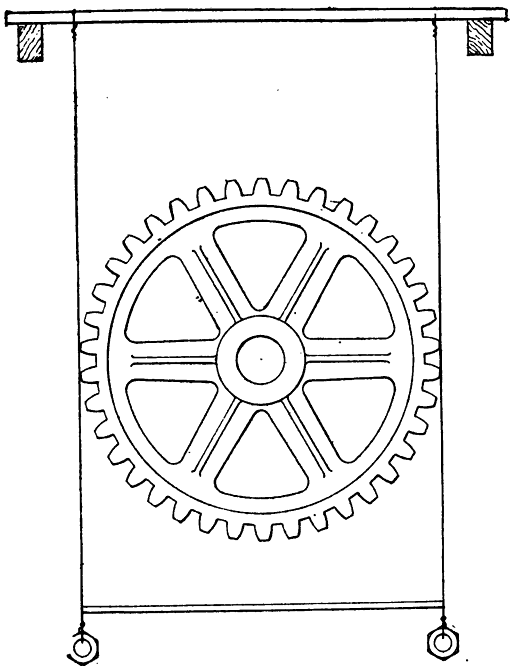


Fig. 337
Obtaining Diameter of Wheel.

taking measurement between them, the dimensions being obtained on both large and small diameters. The lines can always be suspended from beams or other attachments overhead, or from a strip laid over any convenient support somewhere above the wheel. Measurement across can be

taken with a strip, or small iron rod, or large wire, or with a steel tape—not so safely with a linen one.

A templet is made to the bevel of the tooth points Fig. 338 or Fig. 339, whichever happens to be more convenient, and the breadth of the tooth face is scribed upon the templet. A novice would think it sufficient to measure one diameter only, and to take the angle and width of face; or to measure the two diameters and width of face, and omit the angle. In either case the new wheel

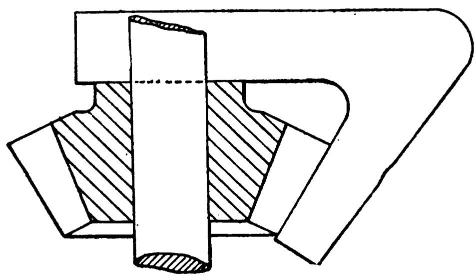


FIG. 338
Obtaining Tooth Angle.

would almost certainly not be exactly like the old one. The reason is, that the roughnesses and inequalities in castings affect every measurement. The consequence is that these little irregularities and discrepancies are easily averaged, when each checks the other.

The templets, shown in Figs. 338, 339, should properly be made in sets of two, one giving the angle at the points of the teeth, the other that at their roots. Of course, in properly designed wheels, these should both run to the apex of the pitch cones, and one could be easily obtained from the other, and from the total length of tooth measured

at one end. But then fitters often have to make bastard wheels to match old ones, which are not properly designed according to standard rules, and for this reason nothing must be taken on trust.

The templet in Fig. 338 is shown fitted against one face of the wheel boss, that in Fig. 339 against a parallel straight-edge, which should bridge over the width of the wheel. A large shaft coming in the way would interfere with this method, while a small one would not. Fig. 338

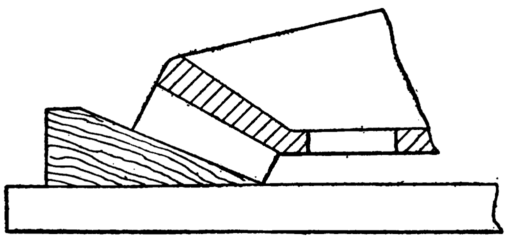


FIG. 339
Obtaining Tooth Angle.

is of sheet iron, tin, or zinc, bent to fit round the shaft; Fig. 339 is of wood.

Rubbings are taken of the teeth at the large end. As a check they may be obtained, too, at the small end. It is sometimes safe to check the bevel of the teeth of old wheels in plan view—that is, to see whether their flanks and faces point to the apex of the cones. They ought to, but they do not always. A templet like Fig. 340, fitted by planing between the teeth, will settle this point. Particulars of bore, boss, and arms follow, and are inserted in a sectional view; width of rims, etc., being marked on the sketch.

If the bevel wheel to be newly made has to work with an existing one, then the latter must be also measured by

the methods just noted in order to the correct matching of the new one to it. If the shaft of the new one is in place, measurement must be taken from that to the teeth of the existing wheel, to get the correct radius, which must determine the number of teeth in the new one.

Being back at shop, the wheels are to be struck out to full size. The sheet with the rubbing is pinned down upon the board, and the pitch circle located and struck. Internal and external templets are made in thin wood to the curve of the pitch circle, and laid in turn upon it. Then generating circles are taken at random, and rolled round on the internal and external curves until a striking point in the circumference of some circle or circles traces the tooth curves. Then those are the circles with which the curves of the teeth of the new wheel will be struck. Very probably there will be found to be a difference in the diameters of the circles, which suit the flanks and faces respectively. Then the circle which suits the flanks of the old wheel must strike the faces of the new one, and the circle which strikes the faces of the old wheel must strike the flanks of the new one. To apply the circles to the new wheel, sweeped templets, inside and outside, must be cut to the pitch curve of the new wheel, and the circles rolled upon these.

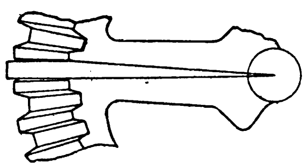


FIG. 340
Obtaining Bevel of Teeth.

So far, the method is identical with that for obtaining the curves of the teeth of spur wheels. But in the case of a bevel wheel the shapes of teeth will be laid down, with circles on the major diameter only. Having obtained

them thus, they are transferred to the minor diameter by drawing lines representing widths and striking centres to the common centre of the two wheels.

Bastard bevel wheels have to be fitted sometimes to existing ones. So-called because their pitch planes do not meet in a common apex. Such a departure from correct form is necessary when a new wheel has to be fitted to an existing one, but in which the relative velocities will not permit of the right number of teeth and right diameter being used, or in which the original wheel is found to be incorrect. The teeth may be less or greater in number, causing the apex of the new wheel to fall short of, or to run beyond that of the existing one. Such wheels, though incorrect in principle, run well if their angles and their tooth shapes are made properly.

To set them out, strike the pitch cones suitably to the number of teeth. Take a templet of the teeth of the old wheel, and find the circles by which its curves were generated. Then strike the teeth of the new wheel to suit.

Mortise gears.—When dimensions have to be taken for re-cogging a mortise wheel, the instructions already given have to be followed for all dimensions. Generally the new cogs have to be prepared without stopping the work. It is then necessary to drive out one of the old ones in order to get the exact size and taper of the mortises to receive the shanks of the new ones. This cog must be carefully measured, or, what is better, a duplicate in deal made, after which it can be replaced until the new ones are ready for insertion.

The tooth curves of the cogs must be obtained from the iron-toothed wheel which has to gear with them, the new ones being made to fit without backlash.

The millwright and sometimes the fitter has awkward work to do in putting a few odd new cogs into old mortise wheels in place, situated in water-wheel pits or close under beams, the wheels being sometimes horizontal, sometimes vertical, and often bevels. The awkwardness of the work is due to the fact that room is cramped, leaving little play for the arms in driving out and fitting in teeth, and little room to use the cutting tools; for frequently the teeth, after their shanks are fitted, have to be shaped in place by the light of a candle or lamp. The reason why a few such cogs have to be fitted is generally due to the teeth having become flaked or *stripped* off. Repairs to broken teeth cannot be made permanent, and so, if badly injured, there is no alternative but to knock them out, and replace with new ones.

In fitting teeth under such conditions the shanks have to be planed and tried from time to time in place until they become a driving fit. The tooth ends and points must be trimmed off after the driving-in has been done. The shapes of the teeth will often be more readily marked by a templet laid against the tooth ends than by compasses. Exact finish is hardly expected in work done under such difficulties. The main point is to get the teeth shanks fitted tightly and secured, and to cut the tooth shapes with a fair degree of accuracy.

Sometimes cogs only partly worn work loose. These can be removed, and replaced by sticking a thickness of canvas down one face of the shank, smearing it well with paint, and driving in afresh.

Cogging new wheels.—The gearing of new mortise wheels is a branch of work in which the millwright takes considerable pride. It is work that fitters in some shops may be expected to do. Every one cannot gear a wheel properly.

It involves the selection of suitable timber, good fitting—neither too hard nor too easy, correct design and shaping of teeth.

The old tooth proportions used for mortise wheels are still adhered to, since they were always made shorter than

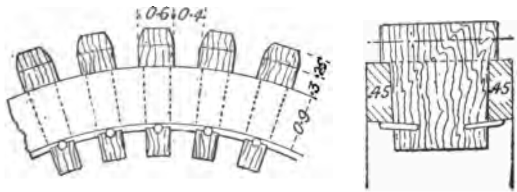


FIG. 341
Proportions of Mortise Wheels.

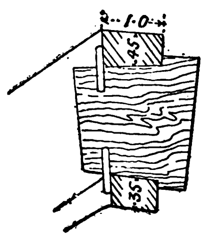


FIG. 342
Proportions of Mortise Wheels.

the teeth of iron wheels which gear with iron wheels. The proportions for spurs and bevels are given in Figs. 341, 342, the unit for proportions being the pitch. The rims look very heavy; but this is unavoidable because of the large amount of metal removed by the mortises. Rims much lighter than those shown by the drawings would inevitably become split, either by the driving-in of the cogs, or by the shocks of working.

The taper of the mortises (shown correctly in the figures)

and their dimensions are a compromise. In reference to the taper, if this were too slight in amount the teeth would work loose; if too much, they could not be driven in with a good frictional grip, but they would tend to start back. The ends of the shanks are not intended to be driven tightly in the same sense as the flanks are—that is, they are only made to fill the mortises closely, while the flanks are fitted tightly by heavy hammer blows. If the ends were driven with a tightly-wedging fit they would split the rim.

The dimensions of the mortises are a mean, leaving sufficient metal between to stand hard driving without fracture, and without reducing the thicknesses of the shanks unduly. Thin shanks would be liable to fracture, and too much overhang of the tooth flanks over the shanks would render them weak, and cause them to flake off during fitting or subsequent working.

The length to which the shank projects within the rim is sufficient to prevent the wood from being thrust or split out by the driving of the pins. The methods of fastening differ, the commonest being pins driven in endwise within the rim, as shown. Wedges, either of iron or wood are alternative methods, with no advantages over the more easily fitted pins.

The rims of mortise wheels, even though made by machine, cannot have internal flanges like many spur wheels, because they would interfere with the driving of the pins. Arms may be of H, or of + section.

When preparing patterns or pattern parts for moulding mortise wheels from, allowance must be made for turning the rim and faces. The mortises in the casting are cleaned out with an old file; otherwise the rough surfaces would interfere somewhat with the good fitting of the cogs.

The timber for cogs, preferably apple tree, hornbeam, oak, or acacia, must be selected free from imperfections of any kind. The harder and tougher the better. If the wheels are to go in a hot shop, the cogs must be perfectly seasoned and absolutely dry. If they are to go into a damp situation they need not be quite so dry. Loose and rattling cogs are a constant source of trouble, and every care should be taken to avoid this evil.

Cogs are easily sawn out and shanked in quantity over a circular saw, by using a templet block, as a guide to uniformity. The amount of allowance to leave from the saw for planing to an exact fit depends on the degree of uniformity existing in the cast mortises. These should be tried round with a wooden templet previous to sawing the shanks, and the shanks be sawn with reference to the largest mortises—should any differences be found to exist. The amount left from the saw to be planed off the shanks need not exceed $\frac{1}{32}$ in. on each face.

The fitting of the shanks is done by driving the cogs in as far as they will go, driving them out again, and noting the parts in contact to be reduced by the rebate plane. When the cog is fitted within about $\frac{3}{8}$ in. of its bedding on the rim, the shoulder is scribed round in place from the rim, the cog removed and cut and planed to the scribed lines. Before being driven in finally it is painted with thick paint, which assists the driving and helps to hold it subsequently.

After the cogs are all driven home and pinned they are turned in place by a templet, cut to their longitudinal sections; the pitch lines and necessary striking lines are then run round. The shapes of the teeth can be struck with a templet, comprising a strip of wood one edge of which is cut to the curve of the tooth points, and across

the face of which a strip of zinc is let in to receive the compass points. Afterwards the teeth are worked with gouge and chisel, assisted at the terminations of the faces by the rebate plane, and are well saturated with boiled oil. The teeth would be cut in a machine if such were available.

CHAPTER XVI

FITTING AND ERECTING SHOPS

THE arrangements of fitting and erecting shops are much varied, according to the class of work done. In some cases the department is quite distinct from the turnery and machine shop, while in others, especially in the case of heavy work, the erecting and the machine shop are intermingled. Sometimes there is a row of machine tools down one side, and a row of benches on the other, while light machine work and fitting may be carried on in galleries. On the other hand, many fitting and erecting shops are set quite apart from the machine shops, and all the parts are transported, by cranes or otherwise from one to the other. In the case of very small machinery, there is usually no advantage in mixing the two departments, since much of the fitters' work consists in mere assembling of parts produced in large quantities. In Plates 1 to 8 some good typical examples of fitting and erecting shops are seen.

Plate 1 (p. 48) shows a machine tool shop, that of Messrs. Kendall & Gent, Ltd., of Manchester. Here the machine tools are grouped chiefly on the right-hand side, and the fitters' benches on the left. Racks for hanging blueprints are seen over the benches. This bay of the shop, like the other to the left, is served with an electric traveller.

Another heavy machine tool shop is that in Plate 2 (p. 96) Messrs. Greenwood & Batley, Ltd., Leeds, in which machines are also intermingled. The fitters to the right are scraping the ways of a heavy planing machine, while the two in the foreground are scraping the facing on the one housing.

Two shops producing lighter classes of tools are seen in Plates 3 (p. 144) and 4 (p. 192). The first is that of Messrs. C. Redman & Sons, Halifax, where the machine tools lie to the left and the fitters benches against the right-hand wall. In the second, that of the Hendey Machine Co., Torrington, Conn., there are a few light lathes and drills for the use of the fitters from time to time.

One of the erecting shops of Messrs. Mather & Platt, Ltd., at Manchester, is seen in Plate 5 (p. 240). Here a miscellaneous class of work is being done, including a big gas engine in the centre foreground, motors and dynamos to the left, while steam engines are also made. There are numerous wall cranes to serve the fitters so as to avoid holding up the overhead traveller for any length of time.

An erecting shop for high-speed engines is seen in Plate 6 (p. 288), Messrs. Willans & Robinson, Ltd., Rugby. A different class of work is shown in Plate 7 (p. 336), including portable engines, and a set of vertical engines of large size. This is the shop of Messrs. J. & H. McLaren, Leeds.

In Plate 8 (p. 384) the controller assembling department of Messrs. Dick, Kerr & Co., Ltd., Preston, is illustrated. The work involves little fitting. The controllers are laid on trestles of the same height as the benches, for convenience of working.

APPENDIX

USEFUL TABLES, NOTES, AND RULES

SCREW THREADS

Formulæ and tables for the principal screw threads are here given. Taking first the Whitworth thread, Fig. 343,

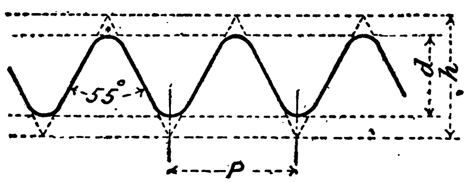


Fig. 343
Whitworth Thread.

the formula is—

$$P = \text{pitch} = \frac{1}{\text{number of threads per inch.}}$$

$$d = \text{depth} = P \times \cdot 64033.$$

$$h = \text{height} = \cdot 9605\ P.$$

One-sixth of the height is rounded off at top and bottom.

The table on p. 372 gives particulars of Whitworth threads up to 6 ins. diameter.

WHITWORTH'S STANDARD SCREW THREADS FOR BOLTS

Diameter of Bolt.		No. of Threads per Inch.	Diameter at Bottom of Thread.	Diameter of Bolt.		No. of Threads per Inch.	Diameter at Bottom of Thread.
Fractional Sizes.	Decimal Sizes.			Fractional Sizes.	Decimal Sizes.		
Inches	Inches		Inches	Inches	Inches		Inches
$\frac{1}{16}$	·0625	60	·0411	$2\frac{5}{8}$	2·625	4	2·3048
$\frac{3}{32}$	·09375	48	·0670	$2\frac{3}{4}$	2·75	3·5	2·3840
$\frac{1}{8}$	·125	40	·0929	$2\frac{7}{8}$	2·875	3·5	2·5090
$\frac{3}{16}$	·1875	24	·1341	3	3·0	3·5	2·6340
$\frac{1}{4}$	·25	20	·1859	$3\frac{1}{8}$	3·125	3·5	2·7590
$\frac{5}{16}$	·3125	18	·2413	$3\frac{1}{4}$	3·25	3·25	2·8559
$\frac{3}{8}$	·375	16	·2949	$3\frac{3}{8}$	3·375	3·25	2·9809
$\frac{7}{16}$	·4375	14	·3460	$3\frac{1}{2}$	3·5	3·25	3·1059
$\frac{1}{2}$	·5	12	·3932	$3\frac{5}{8}$	3·625	3·25	3·2309
$\frac{9}{16}$	·5625	12	·4557	$3\frac{3}{4}$	3·75	3	3·3231
$\frac{5}{8}$	·625	11	·5085	$3\frac{7}{8}$	3·875	3	3·4481
$\frac{11}{16}$	·6875	11	·5710	4	4·0	3	3·5731
$\frac{3}{4}$	·75	10	·6219	$4\frac{1}{8}$	4·125	3	3·6981
$\frac{13}{16}$	·8125	10	·6844	$4\frac{1}{4}$	4·25	2·875	3·8045
$\frac{7}{8}$	·875	9	·7327	$4\frac{3}{8}$	4·375	2·875	3·9295
$\frac{15}{16}$	·9375	9	·7952	$4\frac{1}{2}$	4·5	2·875	4·0545
1	1·0	8	·8399	$4\frac{5}{8}$	4·625	2·875	4·1795
$1\frac{1}{8}$	1·125	7	·9420	$4\frac{3}{4}$	4·75	2·75	4·2843
$1\frac{1}{4}$	1·25	7	1·0670	$4\frac{7}{8}$	4·875	2·75	4·4093
$1\frac{3}{8}$	1·375	6	1·1615	5	5·0	2·75	4·5343
$1\frac{1}{2}$	1·5	6	1·2865	$5\frac{1}{8}$	5·125	2·75	4·6593
$1\frac{5}{8}$	1·625	5	1·3688	$5\frac{1}{4}$	5·25	2·625	4·7621
$1\frac{3}{4}$	1·75	5	1·4938	$5\frac{3}{8}$	5·375	2·625	4·8871
$1\frac{7}{8}$	1·875	4·5	1·5904	$5\frac{1}{2}$	5·5	2·625	5·0121
2	2·0	4·5	1·7154	$5\frac{5}{8}$	5·625	2·625	5·1371
$2\frac{1}{8}$	2·125	4·5	1·8404	$5\frac{3}{4}$	5·75	2·5	5·2377
$2\frac{1}{4}$	2·25	4	1·9298	$5\frac{7}{8}$	5·875	2·5	5·3627
$2\frac{3}{8}$	2·375	4	2·0548	6	6·0	2·5	5·4877
$2\frac{1}{2}$	2·5	4	2·1798				

Pipe threads are given in the table on p. 373.

WHITWORTH'S SCREW THREADS FOR GAS, WATER, AND STEAM PIPING

NOTE.—The diameters for pipes as given below in columns 2, 3, and 5 are those established by "The Engineering Standards Committee for British Standard Pipe Threads"—1905. Those given in columns 4 and 6 are the original "Whitworth" diameters.

Nominal Bore of Tube.	Approximate Outside Diameter of Black Tube. 2	Diameter at Top of Thread. B. S. P. Thread. 3	Diameter at Top of Thread. Whitworth Thread. 4	Diameter at Bottom of Thread. B. S. P. Thread. 5	Diameter at Bottom of Thread. Whitworth Thread. 6	Number of Threads per Inch.
Inches	Inches	Inches	Inches	Inches	Inches	
$\frac{1}{8}$	$\frac{13}{32}$	·383	·3825	·337	·3367	28
$\frac{1}{4}$	$\frac{17}{32}$	·518	·518	·451	·4506	19
$\frac{3}{8}$	$\frac{11}{16}$	·656	·6563	·589	·5889	19
$\frac{1}{2}$	$\frac{27}{32}$	·825	·8257	·734	·7342	
$\frac{5}{8}$	$\frac{15}{16}$	·902	·9022	·811	·8107	14
$\frac{3}{4}$	$1\frac{1}{16}$	1·041	1·041	·950	·9495	
$\frac{7}{8}$	$1\frac{7}{32}$	1·189	1·189	1·098	1·0975	
1	$1\frac{11}{32}$	1·309	1·309	1·193	1·1925	
$1\frac{1}{4}$	$1\frac{11}{16}$	1·650	1·650	1·534	1·5335	
$1\frac{1}{2}$	$1\frac{29}{32}$	1·882	1·882	1·766	1·766	
$1\frac{3}{4}$	$2\frac{5}{32}$	2·116	2·047	2·000	1·9305	
2	$2\frac{3}{8}$	2·347	2·347	2·231	2·2305	
$2\frac{1}{4}$	$2\frac{5}{8}$	2·587	2·587	2·471	2·471	
$2\frac{1}{2}$	3	2·960	3·001	2·844	2·8848	
$2\frac{3}{4}$	$3\frac{1}{4}$	3·210	3·247	·3094	3·1305	
3	$3\frac{1}{2}$	3·460	3·485	3·344	3·3685	11
$3\frac{1}{4}$	$3\frac{3}{4}$	3·700	3·698	3·584	3·582	
$3\frac{1}{2}$	4	3·950	3·912	3·834	3·7955	
$3\frac{3}{4}$	$4\frac{1}{4}$	4·200	4·125	4·084	4·009	
4	$4\frac{1}{2}$	4·450	4·339	4·334	4·2225	
$4\frac{1}{2}$	5	4·950	—	4·834	—	
5	$5\frac{1}{2}$	5·450	—	5·334	—	
$5\frac{1}{2}$	6	5·950	—	5·834	—	
6	$6\frac{1}{2}$	6·450	—	6·334	—	

The sharp Vee thread is used in the United States to a certain extent, but the Sellers' thread is a better type. The Vee thread has an angle of 60°, with no topping off; the Sellers' (Fig. 344), or United States Standard, or Franklin Institute thread is also of 60°, but is flatted at top and bottom to one-eighth the pitch. The principal advantage of this thread is the ease of cutting compared with those threads with rounded points and roots. The formula is—

$$P = \text{pitch} = \frac{1}{\text{number of threads per inch}}.$$
$$d = \text{depth} = P \times \cdot 6495.$$
$$h = P \times \cdot 866.$$

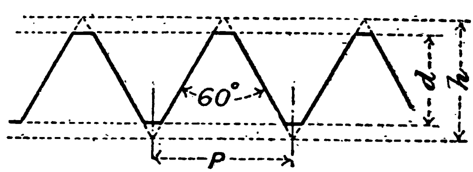


FIG. 344
Sellers' Thread.

The table gives particulars of this thread.

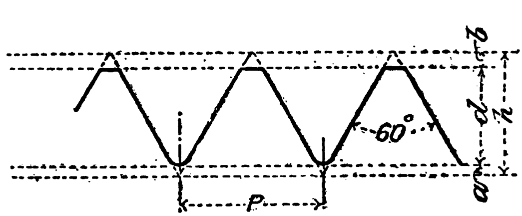


FIG. 345
Système Internationale Thread.

UNITED STATES STANDARD, OR SELLERS' THREAD

Diameter.	No. of Threads per inch.	Diameter.	No. of Threads per inch.
Inches		Inches	
$\frac{1}{4}$	20	2	$4\frac{1}{2}$
$\frac{5}{16}$	18	$2\frac{1}{8}$	$4\frac{1}{2}$
$\frac{3}{8}$	16	$2\frac{1}{4}$	$4\frac{1}{2}$
$\frac{7}{16}$	14	$2\frac{3}{8}$	4
$\frac{1}{2}$	13	$2\frac{1}{2}$	4
$\frac{9}{16}$	12	$2\frac{5}{8}$	4
$\frac{5}{8}$	11	$2\frac{3}{4}$	4
$\frac{3}{4}$	10	$2\frac{7}{8}$	$3\frac{1}{2}$
$\frac{7}{8}$	9	3	$3\frac{1}{2}$
1	8	$3\frac{1}{8}$	$3\frac{1}{2}$
$1\frac{1}{8}$	7	$3\frac{1}{4}$	$3\frac{1}{2}$
$1\frac{1}{4}$	7	$3\frac{3}{8}$	$3\frac{1}{4}$
$1\frac{3}{8}$	6	$3\frac{1}{2}$	$3\frac{1}{4}$
$1\frac{1}{2}$	6	$3\frac{5}{8}$	$3\frac{1}{4}$
$1\frac{5}{8}$	$5\frac{1}{2}$	$3\frac{3}{4}$	3
$1\frac{3}{4}$	5	$3\frac{7}{8}$	3
$1\frac{7}{8}$	5	4	3

The French standard, largely used on the Continent, is the Système Internationale, Fig. 345. The angle is 60°, forming an equilateral triangle; the top is flattened, and the root finished with a radius, which thus gives a radius between bolt and nut. The formula is—

P = pitch.

d = depth = $P \times \cdot 6495$ to $\cdot 704$.

$$a = \frac{h}{16} \text{ to } \frac{h}{24}. \qquad b = \frac{h}{8}.$$

It is thus evident that the clearance may vary, without affecting other relations. A Table is given below—

TABLE OF INTERNATIONAL SCREW THREADS

Diameter in mm.	Pitch in mm.	Diameter at Bottom of Thread in mm.	Diameter in mm.	Pitch in mm.	Diameter at Bottom of Thread in mm.
6	1	4·70	33	3·5	28·45
7	1	5·70	36	4	30·80
8	1·25	6·38	39	4	33·80
9	1·25	7·38	42	4·5	36·15
10	1·5	8·05	45	4·5	39·15
11	1·5	9·05	48	5	41·50
12	1·75	9·73	52	5	45·50
14	2	11·40	56	5·5	48·86
16	2	13·40	60	5·5	52·86
18	2·5	14·75	64	6	56·20
20	2·5	16·75	68	6	60·20
22	2·5	18·75	72	6·5	63·56
24	3	20·10	76	6·5	67·56
27	3	23·10	80	7	70·91
30	3·5	25·45			

The De Lisle, or Löwenherz thread (Fig. 346), used in Germany chiefly, has an angle of 53° 8′, with the total

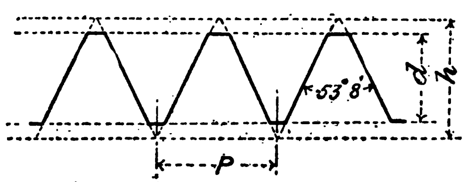


FIG. 346
De Lisle, or Löwenherz Thread.

height h equal to the pitch P. The depth d is obtained by topping off the thread above and below by $\frac{1}{8}$ h.

TABLE OF LÖWENHERZ SCREW THREADS

Diameter in mm. . .	1	1·2	1·4	1·7	2	2·3	2·6	3	3·5
Diameter at Bottom of Thread in mm. . .	0·625	0·825	0·95	1·175	1·4	1·7	1·925	2·25	2·6
Pitch in mm.	0·25	0·25	0·3	0·35	0·4	0·4	0·45	0·5	0·6
Diameter in mm. . .	4	4·5	5	5·5	6	7	8	9	10
Diameter at Bottom of Thread in mm. . .	2·95	3·375	3·8	4·15	4·5	5·35	6·2	7·05	7·9
Pitch in mm.	0·7	0·75	0·8	0·9	1	1·1	1·2	1·3	1·4

The Thury system is of Swiss origin, and is used for watchmaking and for fine mechanism. The angle is 47½°, Fig. 347, the depth $d = \frac{3}{5}$ P. The radii at top and bottom, taken from the total depth h, are point $= \frac{1}{6}$ P and root $= \frac{1}{5}$ P.

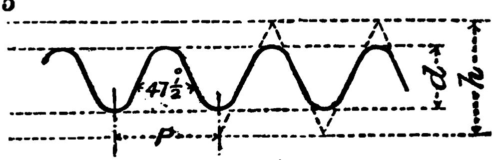


FIG. 347
Thury Thread.

The British Association, or B. A. thread, Fig. 348, used

here largely for small mechanisms and scientific apparatus, is derived from the Thury, but the radii at point and root are similar $= \frac{2}{11}$ of the pitch.

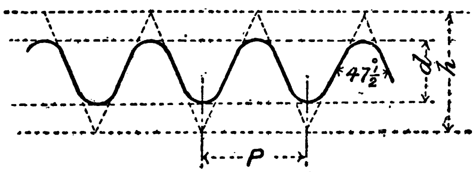


Fig. 348
B. A. Thread.

The table gives B. A. threads in thousandths of an inch, and in metric dimensions also.

BRITISH ASSOCIATION STANDARD THREADS

Number.	Nominal Dimensions in Thousandths of an inch.		Threads per inch.	Absolute Dimensions in millimetres.	
	Diameter.	Pitch.		Diameter.	Pitch.
	Inches			Inches	
25	10	2·8	353	0·25	0·072
24	11	3·1	317	0.29	0·080
23	13	3·5	285	0·33	0·089
22	15	3·9	259	0·37	0·098
21	17	4·3	231	0·42	0·11
20	19	4·7	212	0·48	0·12
19	21	5·5	181	0·54	0·14
18	24	5·9	169	0·62	0·15
17	27	6·7	149	0·70	0·17
16	31	7·5	134	0·79	0·19
15	35	8·3	121	0·90	0·21
14	39	9·1	110	1·0	0·23
13	44	9·8	101	1·2	0·25
12	51	11·0	90·7	1·3	0·28
11	59	12·2	81·9	1·5	0·31
10	67	13·8	72·6	1·7	0·35
9	75	15·4	65·1	1·9	0·39
8	86	16·9	59·1	2·2	0·43
7	98	18·9	52·9	2·5	0·48
6	110	20·9	47·9	2·8	0·53
5	126	23·2	43·0	3·2	0·59
4	142	26·0	38·5	3·6	0·66
3	161	28·7	34·8	4·1	0·73
2	185	31·9	31·4	4·7	0·81
1	209	35·4	28·2	5·3	0·90
0	236	39·4	25·4	6·0	1·00

The Cycle Engineers' Institute thread, or the C. E. I., has an angle of 60°, with one-sixth of the pitch rounded off at point and root, Fig. 349.

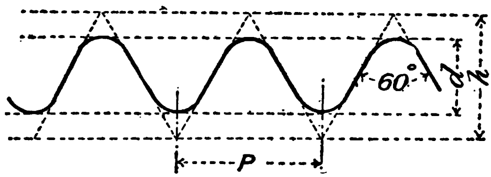


FIG. 349
C. E. I. Thread.

The formula is—

$$d = P \times 0{\cdot}5327$$
$$h = P \times 0{\cdot}866.$$

A table is appended.

CYCLE ENGINEERS' INSTITUTE STANDARD THREADS

All sizes given below are right-hand thread, except where otherwise stated.

Diameter in Decimals and Fractions.		No. of Threads per inch.	Diameter in Decimals and Fractions.		No. of Threads per inch.	Diameter in Decimals and Fractions.		No. of Threads per inch.
Inches			Inches			Inches		
·056	—	62	·154	—	40	·375	$\frac{3}{8}$	26
·064	—	62	·175	—	32	* ·5625	$\frac{9}{16}$	20
·072	—	62	·1875	$\frac{3}{16}$	32	1·000	1	26
·080	—	62	·250	$\frac{1}{4}$	26	**1·290	—	24
·092	—	56	·266	—	26	1·370	—	24
·104	—	44	·281	—	26	**1·4375	$1\frac{7}{16}$	24
·125	$\frac{1}{8}$	40	·3125	$\frac{5}{16}$	26	1·5000	$1\frac{1}{2}$	24

* For right and left-hand thread.
** For left-hand thread only.

The Acme thread (Fig. 350) was brought out in America as a substitute for the square thread. It is used largely for feed screws of various kinds. The angle is 29°, so

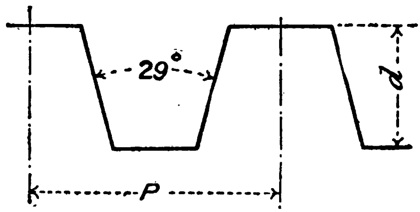


FIG. 350
Acme Thread.

that the sides have an inclination of 14½° similar to the standard worm thread.

The formula is given below, with a table.

The various parts of the Acme Standard Threads are obtained as follows—

Width of point of tool for screw or tap thread

$$= \frac{\cdot 3707}{\text{No. of threads per inch}} - \cdot 0052.$$

Width of screw or nut thread

$$= \frac{\cdot 3707}{\text{No. of threads per inch}}.$$

Diameter of tap

$$= \text{diameter of screw} + \cdot 020.$$

Diameter of tap or screw at root = Diameter of screw

$$- \left(\frac{1}{\text{No. of linear threads per inch}} + \cdot 020\right).$$

Depth of thread

$$= \frac{1}{2 \times \text{No. of threads per inch}} + \cdot 010.$$

The Acme Standard Thread

Number of Threads per inch linear.	Depth of Thread.	Width at top of Thread.	Width at bottom of Thread.	Space at top of Thread.	Thickness at root of Thread.
1	·5100	·3707	·3655	·6293	·6345
$1\frac{1}{3}$	·3850	·2780	·2728	·4720	·4772
2	·2600	·1853	·1801	·3147	·3199
3	·1767	·1235	·1183	·2098	·2150
4	·1350	·0927	·0875	·1573	·1625
5	·1100	·0741	·0689	·1259	·1311
6	·0933	·0618	·0566	·1049	·1101
7	·0814	·0529	·0478	·0899	·0951
8	·0725	·0463	·0411	·0787	·0839
9	·0655	·0413	·0361	·0699	·0751
10	·0600	·0371	·0319	·0629	·0681

The square thread has the width of thread and the depth equal to half the pitch. Absolutely square threads are seldom cut, owing to the difficulty of doing this. Points and roots are usually rounded, and the sides slope slightly.

ELECTRICAL

Ampère.—The unit of strength of current. A pressure of one volt will force a current of one ampère through a resistance of one ohm. If this current is maintained for the duration of a second, one unit of electrical quantity is delivered, this being termed the coulomb.

Volt.—The unit of electrical pressure. A resistance of ohm requires a pressure of one volt to force a current of one ampère through it.

Watt (or Voltampère).—This is the practical unit of

electrical energy. Volts × ampères = watts. An electrical horse power = 746 watts. 1000 watts = one kilowatt, abbreviated as KW.

Ohm.—The unit of electrical resistance—that resistance which would allow an electro-motive force of one volt to pass a current of one ampère. A megohm = 1,000,000 ohms.

Erg.—The centimètre gramme second (or C.G.S.) unit. 13,600,000 ergs = a foot-pound.

Joule.—The practical electric unit of work. Equals 10′ ergs, and represents the work done in one second, when one ampère flows under a P.D. (potential difference) of one volt, or a coulomb passing through a P.D. of one volt.

Electro-motive force, or E.M.F.—That force which tends to force a current through resistance. It is measured in volts.

Dyne.—The absolute unit of force—that which acting on a mass of one gramme moves it through a distance of one centimètre in one second.

Board of Trade unit, or B.T.U.—Equal to 1000 ampère-volt-hours; hence termed the kilowatt-hour. The formula is—

$$\frac{\text{C.E.T.}}{1000} = \text{B.T.U.},$$

where C is the current in ampères, E the electro-motive force in volts, and T the time in hours.

British thermal unit, or B.Th.U.—The amount of heat necessary to raise the temperature of 1 lb. of water through 1° Fahr. at or near 39° 1′ Fahr.

Calorie.—The metric unit of heat; the quantity which is necessary to raise the temperature of one kilogram of water through 1° Cent. at or near 4° Cent. One calorie = 3·9672 B.Th.U.

Specific heat.—The property of a body by virtue of which it shows a change of temperature for a given absorption of heat.

Latent heat.—The specific heat of the state of a body, or that heat which can be put into a body without altering its temperature.

Joule.—The mechanical equivalent of heat. The number of units of work in kilogrammètres necessary to raise by 1° Cent. the temperature of 1 kilogram of water = 424. In English terms the equivalent is that to raise 1 lb. of water say from 40° Fahr. to 41° Fahr. is equivalent to 772 ft. lb. of work.

POWER

Steam engines.—To obtain mean piston speed, multiply twice the stroke in feet by the number of revolutions of the crank shaft per minute. For locomotives, multiply the stroke in feet by the miles per hour travelled by the engine, and by 56·0225, and divide the product by the diameter of the driving wheels in feet. Ordinary horizontal engines run at from 250 ft. to 450 ft. per minute; beam engines for pumping, from 230 ft. to 360 ft.; Corliss mill engines to 700 ft.; high-speed engines, from 500 to 700 ft.; marine engines, from 600 ft. to 900 ft.; torpedo-boat engines, from 1000 ft. to 1200 ft.; locomotives, from 900 ft. to 1200 ft.

Horse power.—H.P. This is equivalent to 33,000 lbs. lifted 1 ft. high per minute; or 1 lb. lifted 33,000 ft. high per minute. Hence the expression, 33,000 *foot-pounds.*

Nominal horse power is simply a commercial term used by makers of engines to denote cylinders of a given bore and stroke. Engines will work up to from two to seven

PLATE. 8.—Shop of Dick, Kerr and Co. Ltd., Preston. [*Facing p.* 384.

or eight times their nominal horse power; dependent on steam pressure and piston speed.

Indicated H.P.—I.H.P. is the measure of the *mean* pressure acting upon the piston throughout its stroke, and is determined by the point of cut-off, the area of the piston, and the piston speed. To obtain I.H.P., multiply the area of the piston in inches by the *mean* or average pressure per square inch, and by the piston speed in feet per minute, and divide the product by 33,000. Or deduce it from indicator cards.

To work out the I.H.P. from an indicator card, divide the card into ten equal parts by lines perpendicular to the atmospheric line, measure the width of the card at the middle of each of these parts on the scale, add the measurements together, and divide the product by 10. The result is the mean pressure on the piston per square inch throughout the stroke. Then multiply the mean pressure by the area of piston in inches, and by the travel of piston in feet, and divide the product by 33,000.

Since a British thermal unit B.Th.U. is equal to 772 foot-pounds, a horse power is equivalent to 42·746 thermal units per minute—that is, 33,000 divided by 772. This mode of calculation is frequently of service when estimating the thermal value of a fuel in horse-power unit.

French H.P.—*force de cheval*—equals 4,500 kilogram-mètres per minute, or 32,549 ft. pounds. One French H.P. is equivalent to ·98,757 English H.P., and the latter is equivalent to 1·0139 French H.P.

Brake H.P.—B.H.P. is the power available for external work after deducting the friction of the engine from the I.H.P. The B.H.P. is obtained in a practical way. Usually a light iron strap having brake blocks of wood

is made to encircle a fly-wheel or pulley driven by the engine, and is loaded with weights and fitted with a spring, *and well lubricated.* Then the B.H.P. is obtained as follows:—Multiply the circumference of the brake circle in feet by the number of revolutions per minute, and by the suspended weight in pounds, and divide the quotient by 33,000. The mechanical efficiency of the engine is, not the I.H.P., but the B.H.P. divided by the I.H.P. The *mechanical efficiency* therefore is the ratio of useful work to work done—that is, the loss due to friction has to be subtracted from the total work. For well-made single-cylinder non-condensing engines it is usual to allow 10 per cent. of the indicated horse power as friction; for small compound non-condensing engines of the portable type, 15 per cent.; and for large compound condensing engines 18 per cent.

Slide valve.—The lap of a slide valve is the amount by which the steam ports are covered when the valve is in *middle* travel. The amount of lap determines the point of cut-off and the expansive working of the steam. *Inside lap* is the amount by which the steam ports are covered by the exhaust edges of the valve when in middle travel. The *lead* of a valve is the amount by which the entering steam edge is open when the piston is beginning its stroke. The *cushioning* of the piston is effected by the confinement of the steam by lead and inside lap, and is made greater in amount in quick than in slow running engines.

Pistons.—The spring of piston rings is allowed for by an increase in their diameter of $\frac{3}{8}$ in. per foot. *Piston stroke* is usually from one and a half times to twice the bore of the cylinder. *Clearance* is the distance between the end or face of the piston when at its extreme position and the cylinder cover. From $\frac{1}{8}$ in. to $\frac{1}{4}$ in. is the clearance space usually allowed. Or, this distance plus the contents of the

steam passage leading to it. The entire contents is usually given as a percentage amount of the piston displacement. This varies from about 2 per cent. in the best Corliss engines where the passages are short, to 12 per cent. in large compound and triple expansion engines.

Expansion.—The pressure of steam expanded in a cylinder is nearly inversely as its volume. The economy of expansion is the difference between the initial pressure and the average pressure.

The diameter of a cylinder for a given indicated H.P. is found thus—

$$\sqrt[2]{\frac{33{,}000 \times \text{number of I.H.P.}}{\cdot 7854 \times \text{mean pressure of steam in pounds per square inch} \times \text{speed of piston in feet.}}}$$

Knowing the initial pressure, or that pressure at which the steam enters the cylinder, and the point of its cut-off, the average pressure throughout the stroke can be readily calculated.

The following table gives mean pressure of steam for various points of cut-off.

The mean pressure due to such expansion is given by the expression :—

$$P_m = P_1\left(\frac{1 + \text{hyp. log. } r}{r}\right) - p.$$

In which P_1 = Absolute initial pressure of steam (= boiler pressure + 14·7 lb.) per square inch.

hyp. log. = Hyperbolic logarithm

r = Ratio of expansion

p = Back pressure = about 4 lb. per square inch in condensing engines, and 17 lb. in non-condensing engines.

P_m = Mean pressure.

TABLE OF STEAM USED EXPANSIVELY

Initial Pressure lbs. per square inch.	Average Pressure of Steam in lbs. per square inch for the whole stroke. Portion of stroke at which steam is cut off.					
	3/4	5/8	1/2	3/8	1/4	1/8
5	4·8	4·6	4·2	3·7	3·0	1·9
10	9.6	9·2	8·4	7·4	5·9	3·8
15	14·5	13·8	12·7	11·2	8·9	5·8
20	19·3	18·4	16·9	14·8	11·9	7·7
25	24·1	22·9	21·1	18·6	14·9	9·6
30	29·0	27·5	25·4	22·3	17·9	11·5
35	33·8	32·1	29·6	26·0	20·8	13·5
40	38·6	36·7	33·8	29·7	23·8	15·4
45	43·4	41·3	38·1	33·5	26·8	3·17
50	48·3	45·9	42·3	37·2	29·8	19·2
60	57·9	55·1	50·7	44·6	35·7	23·1
70	67·6	64·3	59·2	52·1	41·7	26·9
80	77·3	73·5	67·7	59·5	47·7	30·8
90	86·9	82.7	76·1	66·9	53·6	34·6
100	96·6	91·9	84·6	74·4	59·6	38·5
110	106·2	101·1	93·1	81·8	65·6	42·3
120	115·9	110·3	101·5	89·3	71·5	46·2
130	125·6	119·4	110·0	96·7	77·5	50·0
140	135·2	128·6	118·5	104·1	83·4	53·9
150	144·9	137·8	126·9	111·6	89·4	57·7
160	154·6	147·0	135·4	119·0	95·4	61·6
180	173·9	165·4	152·3	133·9	107·3	69·3
200	193·2	183·8	169·2	148·8	119·2	77·0

The maximum economy of expansion cannot be obtained in a single cylinder, because temperature changes with

pressure; with reduced pressure, due to expansion, the cylinder becomes cooled, and produces condensation of some portion of the steam which enters at the succeeding stroke. Moreover, wide variation of pressure causes irregular rotational effort upon the crank pin. These are the reasons why wide grades of expansion are carried out, not in one cylinder, but in two (compounds), three (triple expansion), four (quadruple expansion), cylinders, and the range of pressure between each cylinder, and the loss of heat and condensation, and irregularity of force, are diminished by division between two or more cylinders. When expansion is carried out in a single cylinder, *steam jacketing*, by keeping the cylinder approximately at a uniform temperature, prevents condensation during expansion, and also initial condensation. The final pressure in a low-pressure cylinder may be about 10 lb. or 12 lb. per square inch.

Steam Boilers.—Coal consumption per I.H.P. will range from 3 lb. per hour in non-condensing engines to 2 lb. or less in condensing and compound-condensing engines. Thus condensing stationary engines will average from 1¾ lb. to 2½ lb.; portable engines, 4 lb.; locomotives, from 2 lb. to 2½ lb.; compound marine engines, 2¼ lb. to 2¾ lb.; triple expansion marine engines, 1¼ lb. to 1½ lb.

About 5 or 5½ horse power should be theoretically developed by the combustion of 1 lb. of good coal, estimated only by its thermal value. Actually but a small fraction of this is ever utilized, from about one-twentieth in high pressure non-condensing engines, to about one-tenth in the best compound condensing engines.

The difference between theoretical and actual horse power developed in boilers is due to imperfect combustion, and to the impossibility of applying the actual heat evolved

in a perfect manner to the heating surfaces, and to the water.

The evaporative power of fuel is given in pounds of water evaporated per pounds of fuel. The actual evaporative power is much less than the theoretical. One pound of good coal is estimated to evaporate 14 lb. of water from 100° Fah. to 212° Fah. But actually a vertical boiler will only evaporate from 6 lb. to 7 lb.; while a Galloway boiler will evaporate about $11\frac{3}{4}$ lb. About 8 lb. will be evaporated by a Cornish boiler, and 10 lb. by locomotive and portable engine boilers. Marine boilers will evaporate about $8\frac{3}{4}$ lb.

Evaporative power depends on heating surface and grate area. *Heating surface* is the quantity of boiler surface, estimated in square feet, which is exposed to the water on one side and flame on the other; horizontal surfaces above the flame being reckoned as 1, vertical surfaces are ·5, and tubes and flues are $1\frac{1}{4}$ times their diameter. *Grate area* is the area covered by the fire bars. It bears a definite proportion to heating surface and evaporative power in different types of boilers. The evaporative power of a boiler was long fixed at one cubic foot ($62\frac{1}{2}$ lb. of water) per *nominal* H.P. per hour. But about one-half of this or 30 lb. of water per hour, is amply sufficient for I.H.P. of modern non-condensing engines, and 18 lb. of water per hour is sufficient for modern high-pressure condensing and compound engines. The average water consumption per *indicated* horse power per hour in steam engines may be taken as follows: Non-condensing engines, 25 lb.; condensing engines, 18 lb.; compound engines, 16 lb.; triple expansion engines, $13\frac{1}{2}$ lb.

By *rate of combustion* in steam boilers is meant the weight of fuel in pounds per hour burnt on each square

foot of fire grate. It varies within very wide limits. Averages are as follows: Vertical boilers, 10 lb. to 30 lb.; Cornish, 12 lb. to 14 lb.; Lancashire, 14 lb. to 20 lb.; portable, 9 lb. to 10 lb.; Galloway boilers, 8 lb. to 15 lb.; marine boilers, natural draught, 16 lb. to 24 lb.; locomotives burning coal, 40 lb. to 65 lb.

The proportions of heating surface to grate area range from 10 to 1 respectively in externally-fired boilers; between 60 and 90 to 1 in locomotive boilers; in Cornish boilers and Lancashire boilers between 15 and 25 to 1; in multitubular boilers between 30 and 40 to 1; vertical boilers between 15 and 25 to one; marine boilers between range 27 and 35 to 1. The heating surface of the tubes of a locomotive boiler is usually 10 or 12 times greater than that of the fire-box. The total heating surface of a locomotive boiler should equal the diameter of one cylinder squared and multiplied by 4. To obtain the heating surface of the boiler tubes, multiply the external circumference of the tubes by the length between the tube plates. To obtain the heating surface of the tube plates, deduct the area of the tube holes from the area of the plates.

The evaporative power of steam boilers is also given in terms of the heating surface, taken as square feet, as follows: For each square foot of heating surface a vertical boiler with cross tubes will evaporate 2¼ lb. of water per hour; a Lancashire boiler, 2½ lb.; a Galloway boiler, 3 lb.; a portable engine boiler, 2¾ lb.; a locomotive boiler, 8 lb. to 9 lb.; a marine boiler with natural draught, 5 lb.; or with forced draught, 14 lb.

The nominal horse power of a boiler is estimated by the number of cubic feet of water which it will evaporate in one hour. One cubic foot of water evaporated per hour is equivalent to one nominal horse power.

An approximate rule by measurement is, multiply the length of the boiler by the diameter in feet, and divide by 6. Speaking generally, 12 square feet of heating surface, and from $\frac{3}{4}$ of a foot to one square foot of fire-grate area are required per nominal horse power.

PUMPS

Bore.—The diameter of the bore of a single-acting pump in inches is obtained by dividing the number of gallons to be delivered per minute by the product of ·034 × the length of stroke in feet × the number of strokes per minute, and taking the square root of the product so obtained. Note.—The number of *gallons* delivered *per minute* is equal to the product of ·034 × diam. in inches squared × length of stroke in feet × the number of strokes per minute. Or, let D = the diameter or bore of a pump in inches, and S = its stroke in inches. Then D squared × S × ·7854 = cubic inches. D squared × S × ·0,000,545 = cubic feet. D squared × S ·002,833 = gallons. D squared × S × ·02,833 = pounds of fresh water.

The *modulus* of a machine is its net efficiency after deducting losses due to construction, weight, and friction from the theoretical efficiency. The moduli of pumps are as follows: Common lifting pumps, ·5; ordinary force pumps, ·66; air pumps, ·56 to ·66; low lift centrifugal pumps, ·5. The theoretical horse power of a pump must be multiplied by the modulus in order to obtain its net efficiency. And the quantity of water delivered from a pump is equal to its capacity multiplied by the modulus. The capacity of a pump barrel in inches is equal to the area in square inches multiplied by the length of stroke in inches. The quantity delivered per hour equals the net

quantity delivered per stroke, multiplied by the number of strokes per minute, multiplied by 60. And the quantity in cubic feet equals the quantity in cubic inches divided by 1,728. The time required to pump a given quantity of water is obtained by dividing the quantity in cubic feet or inches to be pumped by the number of cubic feet or inches discharged per hour.

LIQUIDS

Tanks.—To obtain the *weight in pounds of water* in a tank. Multiply the length, breadth, and depth together in feet, and multiply the product by 62·5 for the weight of fresh water, and by 64 for the weight of sea water. To obtain the quantity of water in gallons, multiply the cubical contents in feet by 6·25 for fresh water, and by 6·4 for sea water.

The size of a rectangular tank in feet required to hold a given quantity of fresh water is found as follows—

$$\text{Depth of tank} = \frac{\text{number of gallons}}{\text{length} \times \text{width} \times 6{\cdot}25}$$

$$\text{Width of tank} = \frac{\text{number of gallons}}{\text{length} \times \text{depth} \times 6{\cdot}25}$$

$$\text{Length of tank} = \frac{\text{number of gallons}}{\text{width} \times \text{depth} \times 6{\cdot}25}$$

The size of a circular tank in feet to hold a given quantity of water is found as follows—

$$\text{Height} = \frac{\text{number of gallons}}{\text{diam.}^2 \times {\cdot}7854 \times 6{\cdot}25}$$

$$\text{Area} = \frac{\text{number of gallons}}{\text{height} \times 6{\cdot}25}$$

$$\text{Diam.} = \sqrt[2]{\text{area} \div {\cdot}7854}$$

A column of air 1,893 ft. high at 32° Fah., of uniform density equal to that of air at sea level, will equal a pressure of 1 lb. per square inch. The mean atmospheric pressure at sea level and 32° Fah. is 14·7 lb. per square inch, taken roughly in calculation at 15 lb., equivalent to 2,116·8 lb. per square foot.

A column of mercury 29·922 ins. high at 32° Fah. will balance the mean atmospheric pressure at sea level; usually taken as 30 ins. of mercury.

A column of water 1 in. square, 33·947 ft. high, at 60° Fah. will balance the mean atmospheric pressure; usually taken as 34 ft. of water. A column of mercury 2 ins. high at 32° Fah. equals a pressure of 1 lb. per square inch.

Water in freezing expands about $\frac{1}{12}$ of its original volume, and its expansive force at the moment of freezing is estimated at about 32,000 lbs. per square inch.

Ordinary *sea water* contains $\frac{1}{33}$ part of its weight of salt, and this is called *one degree* of saltness.

The following table will be found useful in calculations relating to heads and pressures of water.

It contains equivalent pressures per square inch for various heads from one to a thousand feet. Pressures for higher numbers not given in the table can be obtained by adding or subtracting the lower numbers.

This is followed by a number of standard measurements by which hydraulic calculations can be much facilitated.

PRESSURE OF WATER FOR GIVEN HEADS

Head.	Pressure per sq. inch.	Head.	Pressure per sq. inch.	Head.	Pressure per sq. inch.	Head.	Pressure per sq. inch.
Feet	Pounds	Feet	Pounds	Feet	Pounds	Feet	Pounds
1	0·43	40	17·32	98	42·45	240	103·96
2	0·86	42	18·19	100	43·31	245	106·13
3	1·30	44	19·05	105	45·48	250	108·29
4	1·73	46	19·92	110	47·64	255	110·46
5	2·16	48	20·79	115	49·81	260	112·62
6	2·59	50	21·65	120	51·98	265	114·79
7	3·03	52	22·52	125	54·15	270	116·96
8	3·46	54	23·39	130	56·31	275	119·12
9	3·89	56	24·26	135	58·48	280	121·29
10	4·33	58	25·12	140	60·64	285	123·45
11	4·76	60	25·99	145	62·81	290	125·62
12	5·20	62	26·85	150	64·97	295	127·78
13	5·63	64	27·72	155	67·14	300	129·95
14	6·06	66	28·58	160	69·31	310	134·28
15	6·49	68	29·45	165	71·47	320	134·62
16	6·93	70	30·32	170	73·64	330	142·95
17	7·36	72	31·18	175	75·80	340	147·28
18	7·79	74	32·05	180	77·97	350	151·61
19	8·22	76	32·92	185	80·14	360	155·94
20	8·66	78	33·78	190	82·30	370	160·27
22	9·53	80	34·65	195	84·47	380	164·61
24	10·39	82	35·52	200	86·63	390	168·94
26	11·26	84	36·39	205	88·80	400	173·27
28	12·12	86	37·25	210	90·96	500	216·58
30	12·99	88	38·12	215	93·13	600	259·90
32	13·86	90	38·98	220	95·30	700	302·22
34	14·72	92	39·85	225	97·46	800	346·54
36	15·59	94	40·72	230	99·63	900	389·86
38	16·45	96	41·58	235	101·79	1000	433·18

HYDRAULIC MEMORANDA

The freezing point under one atmosphere is 32° Fah., or 0° Cent.

The point of maximum density is 39·1° Fah., or 4° Cent.

The British Standard temperature is 62° Fah., or 16·66° Cent.

The boiling point under one atmosphere is 212° Fah., or 100° Cent.

Weight of one cubic inch of pure water at 32° = ·03612 lb.; at 39·1° = ·036125 lb.; at 62° = ·03608 lb.; at 212° = ·03451 lb.

Weight of one cubic foot of pure water at 32° = 62·418 lb.; at 39·1° = 62·425 lb.; at 62° = 62·355 lb.; at 212° = 59·640 lb. Volume or bulk of 1 lb. of pure water at 32° = 27·684 cubic inches; at 39·1° = 27·680 cubic inches; at 62° = 27 cubic inches; at 212° = 28 cubic inches.

The weight of one gallon of pure water at 62° (the standard temperature) is 10 lb. One gallon of pure water at 62° (the standard temperature) is ·0045 of a ton.

The weight of 11·2 gallons of pure water = 1 cwt.

The weight of 224 gallons of pure water = 1 ton.

One cubic foot of water contains 6·2355 gallons, or roughly $6\frac{1}{4}$ gallons.

1·8 cubic feet = 1 cwt.

27 cubic feet or 1 cubic yard weighs 15 cwt.

36 cubic feet (35·84) = 1 ton.

One cubic foot of water weighs ·577 cwt., and ·028 of a ton.

One lb. of water contains 27·72 cubic inches, or ·10 of a gallon.

An imperial gallon = 277·274 cubic inches, or ·16045 cubic feet.

A cylindrical inch of water = ·0284 lb.

A cylindrical foot weighs 48·961 lb.

Capacity of a cubic inch of water = ·003606 gallons.

Capacity of a cylindrical inch = ·002832 gallons.

Capacity of a column 1 inch square 1 foot long = ·0434 gallons.

Capacity of a column 1 foot dia. 1 foot long = 4·896 gallons.

Capacity of a column 1 inch dia. 1 foot long = ·034 gallons.

Capacity of a sphere 1 inch dia. = ·00188 gallons.

Capacity of a sphere 12 inches dia. = 3·263 gallons.

THE ATMOSPHERE

Atmospheric resistance to moving bodies increases as the square of their velocity. The atmospheric resistance per square foot of frontage increases as the square of the velocity in feet per second, multiplied by ·0017. On railways the atmospheric resistance, independent of winds, is taken as equal to three or four pounds per ton of the weight of the engine, tender, and train; with ordinary side winds this amount is about doubled.

A maximum pressure of 56 lb. per square foot should be assumed for the purpose of calculation of the stresses on railway bridges and viaducts. The pressure on roofs seldom exceeds 40 lb. per square foot. A pressure of 56 lb. per square foot corresponds with the mean wind velocity of 75 miles per hour. The formula for wind pressure is $\frac{\text{velocity}^2}{100}$ = pressure.

GEARING

A *train* of gearing is essentially a system of levers, hence power and speed, friction being disregarded, are strictly proportional. The *power of gearing* is estimated by dividing the product of all the wheels by the product of all the pinions. To find the *final speed* of a train of gearing, multiply the number of revolutions per minute of the first driving wheel by the product of the diameters of the driving wheels, and divide the result by the product of the diameter of the driven wheels.

The following rules will be found of service. They comprise the ratios of teeth, pitch, and diameter, and the strength, proportions, and weight of wheels.

RATIO OF WHEELS

Having two proportional factors of a wheel given, to find the third—

Let π = ratio of circumference to diameter = 3·14159.

n = number of teeth.

d = p. diameter in inches.

p = pitch of teeth.

Then (1) the diameter and pitch being given, to find the number of teeth—

$$n = \frac{\pi \times d}{p}$$

(2) The number of teeth and diameter being given, to find the pitch—

$$p = \frac{\pi \times d}{n}$$

(3) The number of teeth and pitch being given, to find the diameter—

$$d = \frac{n \times p}{\pi}$$

The *strength* of wheel teeth to resist a dead load is obtained thus—

Square the depth at the root, multiply by the breadth, and by a multiplier representing the strength of the material of which the gearing is made, and divide the product by the length of the tooth, that is—measured from root to point.

To obtain the dynamic strength of wheel teeth in terms of horse power, multiply the stress at the pitch line in pounds by the velocity in feet per minute, and divide by 33,000. Or, square the pitch of the teeth in inches, multiply by the breadth of face in inches, and by the diameter of the wheel in feet and by the number of revolutions per minute, and divide the product by 240.

The *power* of wheels is directly proportionate to the speed at pitch line.

Shrouding wheels increases the strength of the teeth by reducing their length considered as cantilevers. The strength of bevel-wheel teeth is calculated on the mean diameter and the mean pitch.

The old *proportions* given to wheel teeth were as follows: Divide the pitch into 15 equal parts, the total length of tooth will equal 12 of these parts, the length from pitch line to point $5\frac{1}{2}$ parts, the length from pitch line to root $6\frac{1}{2}$ parts, tooth thickness 7 parts, and tooth space 8 parts. But see p. 253 for present practice.

To find the *Weight* of Wheels.

(D. K. Clark) $W = (\cdot 05 + \cdot 08\,p)\,d\,(1 + 0\cdot 10\,d)$

where d = diameter in feet.

p = pitch in inches.

$\cdot 05$ = constant

W = weight per inch of breadth.

Bevel wheels to be taken at $\frac{2}{3}$ to $\frac{3}{4}$ of the spur wheels.

(Unwin) $W = R\,N\,b\,p^2$.

where p = pitch.

b = breadth of face.

N = number of teeth.

R = 0·38 for spur wheels, 0·325 for bevels.

(Box) $W = (D \times P \times W) + (\sqrt{D \times P \times W}) \times M$

where D = pitch diameter in feet.

P = pitch in inches.

W = width on face in inches.

M = 12 for spur wheels, 10 for bevels.

W = weight in lbs.

PULLEYS

To find the speed of a *driven* pulley multiply the diameter in inches of the driving pulley by the number of revolutions it makes per minute, and divide the product by the diameter in inches of the driven pulley. To find the *speed* of a *driving* pulley, multiply the diameter in inches of the driven by its number of revolutions per minute, and divide the product by the diameter in inches of the driving pulley. To find the *diameter* of a *driven* pulley, multiply the diameter in inches of the driving pulley by its number of revolutions per minute, and divide the product by the number of revolutions of the driven. To find the *diameter* of a *driving* pulley, multiply

the diameter in inches of the driven by its number of revolutions per minute, and divide the product by the number of revolutions of the driving pulley.

KEYS AND COTTARS

The following gives ordinary proportions of keys and cottars.

Ordinary proportions of keys: Width of key = one-fourth diameter of shaft up to 4 in.; one-fifth diameter of shaft from 4 in. to 8 in.; and one-sixth diameter of shaft from 8 in. to 12 in. Key to be square at thick end, one-third thickness let into shaft, remainder in wheel.

Proportions of cottars through bars: b = breadth of cottar; t = thickness of cottar; d = diameter of bar.

Through round bars, $b = 1{\cdot}463\ d;\ t = \frac{d}{5}$.

Through square bars, $b = 1{\cdot}5$ side of bar, $t = \frac{\text{side of bar}}{4}$.

SHAFTING

The nominal horse power of shafts may be obtained as follows: Multiply the cube of the diameter in inches by the number of revolutions per minute, and divide the product by 190 for wrought iron or by 92 for steel.

To find the *diameter* of a shaft capable of transmitting a given horse power, multiply the horse power by 190 for wrought iron and 92 for steel, and divide by the number of revolutions per minute. The cube root of the quotient is the diameter of the shaft in inches.

To find the speed required for transmitting the given horse power, multiply the given horse power by 190 for wrought iron or 92 for steel, and divide the product by

the cube of the diameter in inches. The quotient equals the number of revolutions per minute.

These rules require to be modified in the case of small shafts of exceptional lengths.

The actual or indicated horse power might be nearly double the nominal. The horse power developed equals the work done in one revolution multiplied by the number of revolutions per minute and divided by 33,000.

BELTING

The actual *horse power* of belts equals the force in pounds transmitted to the surface of the pulley, multiplied by the velocity of the belt in feet per minute, and the quotient divided by 33,000.

The working tension of leather belts should not exceed 300 to 330 lb. per sq. inch per section.

Single leather belts are $\frac{3}{16}$ in. thick. Assuming a maximum stress of 60 lb. per inch of width, we multiply the breadth of belt in inches and its speed per minute by 60, and dividing this by 33,000 will give the horse power transmitted.

Double belts transmit from $1\frac{1}{2}$ times to twice the power of single belts. Short belts are more liable to slip than long ones. From 3000 to 4000 feet per minute is the maximum speed for belts. Lathe belts run at half this speed.

The convexity of pulleys should range from $\frac{1}{8}$ in. to $\frac{1}{4}$ in. per foot in width.

MATERIALS—STRESS TERMS

The *load* usually signifies not only the aggregate of the

external forces acting on a structure but also the weight of the structure itself.

The *test load* signifies that by which the strength of a structure short of its elastic limit is determined. Also called the *proof load.*

The *working load*, or the *safe working load*, is that beyond which the structure is not stressed in actual practice.

The *ultimate or breaking strength* divided by the safe working load gives the factor of safety.

A *dead load* or *statical load* is one which is applied gradually, and which remains unaltered in amount or in intensity.

A *live or variable load* is one which is put on suddenly, and is intermittent in amount and irregular in action. A smaller factor of safety is permissible in the case of a dead load than in that of a live load.

Stress signifies the internal forces or resistances set up in a material or structure in opposition to external forces.

Strain signifies the change of form in a material or structure produced by the action of a load.

Tensile stress signifies the resistance offered by a body to forces tending to pull it asunder. The result is elongation.

Compressive stress or *crushing stress* signifies the resistance offered by a body to forces tending to crush it. The result is compression, shortening, and lateral deflection.

Shearing stress signifies the resistance offered by a body to forces tending to sever or cut it through in a plane at a right angle or nearly so to its longitudinal axis. The result is deflection and elongation.

Torsional stress signifies the resistance offered by a body

to forces tending to twist it off. The result is angular deflection.

The elastic limit or the *elastic strength* of a material coincides with the amount of stress which a material or structure can endure without permanent set. The limit of elastic strength is sometimes termed the dangerous limit, because no material or structure should be stressed up to that limit.

Set signifies the alteration in form which a body undergoes when subjected to stress.

Permanent set is that alteration in form from which a body does not recover after the load has been removed.

The fatigue of a material signifies a degeneration due to molecular change which the material has undergone by reason of the frequently repeated action of live loads.

Elongation under tensile stress denotes the amount of extension which a test specimen undergoes between the application of the load and the fracture of the test piece. It is usually given as a percentage quantity of the original length of the test piece.

Contraction of area under tensile stress signifies the reduction of area between the application of the load and the fracture of the test piece. It is given as a percentage quantity of the original sectional area of the test piece.

The mere *tensile strength* of a material is of no value apart from its relation to elongation and contraction of area. For most structural purposes the best material is that which combines a high percentage of elongation and contraction of area with a moderate tensile strength.

IRON CEMENTS

1. Iron cement (rust joint).—Cast iron borings 112 lb; sal-ammoniac 1 lb.; sulphur 1 lb.; whiting 4 lb.

2. Another (quickly setting).—Sal-ammoniac 1 lb.; flour of sulphur 2 lb.; iron borings 80 lb.
3. Another (slowly setting).—Sal-ammoniac 2 lb.; flour of sulphur 1 lb.; iron borings 200 lb.

   These are mixed into a paste with water just previous to use, and driven in with a caulking iron.
4. For cracks in metal work, use filings instead of borings; or—iron filings 16; sal-ammoniac 3; flour of sulphur 2; mix, and keep stoppered. For use, take 1 part of the mixture, 12 parts of new filings, add a few drops of sulphuric acid, and fill the joint.
5. Or boiled linseed oil, litharge, and red and white lead. Apply on each side of a piece of flannel or paper, and lay between opposing faces, which have to be pulled together.
6. Iron cement unaffected by red heat.—Iron filings 4 lb.; clay 2 lb.; pounded firebrick or Hessian crucible 1 lb.; mix to a stiff paste with a saturated solution of salt.
7. Or iron filings, sal-ammoniac, and borax.
8. Lutes for crucibles and furnace joints.—Clay 2 parts; sharp sand 8 parts; horse dung 1 part.
9. Or linseed meal mixed to a paste with milk, lime water, or starch paste.
10. Or plaster of Paris, mixed with water, milk, or weak glue. These two last are for low temperatures.

GLUES

11. To resist moisture.—1 lb. glue melted in 2 quarts of skimmed milk.
12. Or, glue 1, black resin 1, red ochre $\frac{1}{4}$, melt and mix.

13. Strong glue.—Add powdered chalk to common glue.
14. Another.—Infuse glue and isinglass in alcohol, heat gently, and add powdered chalk.
15. Another.—Glue 4, boiled oil 1, oxide of iron or red lead 1.
16. Another.—Soak ordinary glue for 12 hours in cold water, pour off the water, and add sufficient glacial acetic acid; dissolve in a hot-water bath.
17. Another.—To ordinary glue, add $\frac{1}{4}$ part vinegar, and a little glycerine, mix plaster of Paris to the required consistency.
18. Liquid glue.—White glue 1 lb.; white lead, in powder 4 oz.; soft water 2 pints; alcohol 4 oz.; stir and bottle while hot.
19. Elastic glue.—Dissolve glue in a water bath, evaporate to a thick fluid, and add an equal weight of glycerine; cool on a slab.
20. Marine glue.—Shellac and indiarubber dissolved in separate portions of naphtha, and mixed.
21. Another.—Indiarubber 1; mineral naphtha 12; heat gently, mix, and add powdered shellac 20. Pour on a slab to cool—when used, to be heated to about 250°.

VARIOUS CEMENTS

22. Turner's cement.—Black resin 8; yellow wax 1; melted. Cover the chuck to $\frac{1}{16}$ in. thick, mixing with it $\frac{1}{8}$ of its bulk of guttapercha in thin slices. Heat and iron to dull red, and hold it over the chuck till the mixture is melted together, then stir with the iron, chuck the work, lay a weight on, and leave to set.

23. Another.—Burgundy pitch 2 parts; resin 2; yellow wax $\frac{1}{8}$; dried wax 2; melt and mix.
24. Another.—Resin 4 parts; pitch 1; melt, and, while boiling, add brickdust, until dropping a little on stone shows the mixture to be sufficiently hard.
25. Another.—Resin $\frac{1}{2}$ lb.; wax 1 oz.; and any fine powder.
26. Another.—Shellac mixed with half its weight of pumice stone.
27. For leaky boilers.—Powdered litharge 2 parts; fine sand 2; slaked lime 1; mix with boiled linseed oil, and apply quickly.
28. For emery on to wood.—Equal parts of shellac; white resin and carbolic acid in crystals; add the acid after the others are melted.
29. For indiarubber or leather.—Bisulphide of carbon 4 oz.; shredded indiarubber 1 oz.; isinglass 2 drachms; guttapercha $\frac{1}{2}$ oz.; dissolve, coat the parts, dry, then heat the layer to melting; place and press the parts together.
30. For leather belts.—Guttapercha 3; pure white raw indiarubber 1; dissolved in 8 of bisulphide of carbon.
31. Another.—Guttapercha 16; pure white raw indiarubber 4; dissolve; then add pitch 2; shellac 1; boiled linseed oil 2.
32. To cover an iron pulley with leather.—Nut galls crushed, 1 part; dissolved for 6 hours in distilled water 8 parts, and applied hot to the leather. Take the same quantity of water as that used for the nut galls, and place in it one part by weight of glue, which is held in solution for 24 hours, and then applied to the pulley, which is roughened and heated. The leather is then laid on the metal and dried under pressure.

33. Another.—Isinglass 1 part; fish glue 5 parts; dissolved in water 6 parts; then add carefully nitric acid 1 part.

34. Steam joints.—White lead 1 part; red lead 1 part; mixed with boiled linseed oil to a thick paste.

35. Another, to stand heat.—Plumbago 1 part; red lead 1; white lead 1; mixed as before.

36. For steam and water.—White lead 10; black oxide of manganese 3; litharge 1; mixed as before. These are used alone, or in conjunction with sheets of wire gauze, American cloth, millboard, or coils of copper or lead wire.

37. Aquarium cement.—For fresh water, gold size ½ gill; red lead 2 gills; litharge 1½ gills, and sufficient silver sand to make a thick paste. Sets in 2 days.

38. For fresh or salt water.—Powdered resin ⅓ gill; white sand 1 gill; litharge 1 gill; plaster of Paris 1 gill; sifted and mixed with boiled linseed oil, adding a little dryers; mix 15 hours before using. Sets in 2 or 3 hours.

39. Electric cement.—Beeswax 1 lb.; resin 5 lb.; red ochre 1 lb.; plaster of Paris 2 oz.

40. Metal and glass. Copal varnish 16; drying oil 6; Venice turpentine 3; melt and add powdered quicklime 10.

CONCRETES, ETC.

41. Concrete for blocks or walls.—Clean gravel or shingle 6½ parts; sand 2½; Portland cement 1.

42. Another.—Lime 1; gravel 4; sand 2.

43. Another.—Hydraulic lime, measured before slacking 33; puozzolano 45; sand 22; gravel or broken stone 60.

44. Another.—Sand 3; hydraulic lime unslacked 1; gravel or broken stone 4.
45. Hydraulic mortar.—Blue lias lime 1; burnt clay 2½; ground together.
46. Another.—Blue lias lime 1; sharp sand 6; puozzolano 1; calcined ironstone 1.
47. Ordinary mortar.—Lime 1; sharp red sand 2 to 3.

LUBRICANTS

For light machinery, sperm olive, or equal parts of good mineral oil and sperm oil.

For heavy machinery, rape or castor oil.

For heated machinery, neat's foot oil mixed with tallow and plumbago.

Compound oils are preferable to simple oils.

For metal and wood, water is the best lubricant.

ANTIFRICTION MIXTURES

Sulphur, blacklead, or plumbago, finely powdered and mixed with oil or tallow.

Hog's lard, guttapercha, and powdered blacklead.

Lubricating paraffin oil 1 gallon; solid paraffin 2 lb.; plumbago 2 lb.; melt and mix together.

Tallow 1¾ cwt.; palm oil 1¼ cwt. When boiling point is reached allow it to cool to blood heat, stirring it meanwhile; then strain through a sieve into solution of ½ cwt. of soda in 3 gallons of water, mixing well.

For winter 1¼ cwt. of tallow to 1¾ cwt. of palm oil. For spring and autumn equal parts.

For axles, tallow 8 lb.; palm oil 1 gallon; mineral oil 1 gallon; plumbago 1 lb.; melt and mix.

Water 1 gallon; mineral oil 1 gallon; tallow 4 lb.; palm oil 6 lb.; soda ½ lb.; mix and melt.

Blacklead 1, tallow 4; mix and grind smooth.

Scotch soda 1 lb.; boiling water 8 gallons; palm oil or tallow 10 lb.; agitate till cooled to 65° F.

For mortise wheels, soft soap and plumbago.

Leather dressing, castor oil 2 quarts; tallow 1 lb.; powdered resin 1 oz.; hard soap 2 oz.; melt and mix.

Waterproof dressing, beeswax 1 oz.; powdered resin 1 oz.; soap 3 oz.; castor oil 1 pint; boiled oil 1 quart; boil; and afterwards thin with warm oil of turpentine.

GAUGES

Birmingham wire gauge. In the appendix to the second volume of Holtzapffel's work on "Turning and Mechanical

OLD B. W. G.

Descriptive No. B. W. G.	Equivalent Parts of an inch.	Descriptive No. B. W. G.	Equivalent Parts of an inch.	Descriptive No. B. W. G.	Equivalent Parts of an inch.
0000	·454	11	·120	24	·022
000	·425	12	·109	25	·020
00	·380	13	·095	26	·018
0	·340	14	·083	27	·016
1	·300	15	·072	28	·014
2	·284	16	·065	29	·013
3	·259	17	·058	30	·012
4	·238	18	·049	31	·010
5	·220	19	·042	32	·009
6	·203	20	·035	33	·008
7	·180	21	·032	34	·007
8	·165	22	·028	35	·005
9	·148	23	·025	36	·004
10	·134				

Imperial Wire Gauge

This table of sizes was drawn up by the Iron and Steel Wire Manufacturers' Association in 1884.

Dimensions of Sizes in Decimal Parts of an Inch

Number of Wire Gauge.	Size.	Number of Wire Gauge.	Size.	Number of Wire Gauge.	Size.	Number of Wire Gauge.	Size.
000000	·464	7	·176	19	·040	30	·0124
00000	·432	8	·160	20	·036	31	·0116
0000	·400	9	·144	21	·032	32	·0108
000	·372	10	·128	22	·028	33	·0100
00	·348	11	·116	23	·024	34	·0092
0	·324	12	·104	24	·022	35	·0084
1	·300	13	·092	25	·020	36	·0076
2	·276	14	·080	26	·018	37	·0068
3	·252	15	·072	27	·0164	38	·0060
4	·232	16	·064	28	·0149	39	·0052
5	·212	17	·056	29	·0136	40	·0048
6	·192	18	·048				

Manipulation," p. 1012, an account is given of the principal gauges then in use, together with a proposal for "an easy and exact system of gauges for sheet metals, wires, and general purposes, founded on the decimal division of the inch." This design, in conjunction with Mr. Stubs, of Warrington, was carried into effect. From a number of gauges Mr. Holtzapffel selected the B.W.G. proper, the B. sheet-metal gauge, and the Lancashire gauge used exclusively for steel wire ; and having shown their want of uniformity, he proposed to remove the arbitrary incongruous system of gauges used, and to employ the decimal divisions of the

inch, and those under their true appellations. Mr. Holtzapffel tested the best drifts in the possession of Mr. Stubs, and determined the sizes, and authoritatively, giving them in thousandths of an inch, and these have been adhered to by Mr. Stubs since, and are now the best gauges in use. But unfortunately there are so many other gauges in use that confusion exists at the present day.

WEIGHTS

The estimation of the weights of bars, both round and square, is taken directly from tables. It is simply a question of width, thickness, and a length of 12 inches multiplied by the number of feet run in bars of the given section. In the case of other rolled sections, as angles, tees, channels, joists and other irregular forms, the weights are usually taken direct from tables, either given in books of reference, or in the maker's lists, or they may be calculated. The weights of channels and joists of given dimensions are better taken directly from the manufacturer's price lists. Angles and tees vary so greatly in width and thicknesses, however, that an exhaustive table of weights of these would make a bulky volume. Only the weights of some of the commoner angles and tees are therefore given in books of reference. It is therefore most usual to estimate the weights of these by calculating their *united inches,* and then reckoning out the weight per foot run. By "united inches" is meant the total number of square inches in the cross section. Thus an angle measuring 5 in. × 5 in. × 1 in. would have 9 united inches in its cross section, and the weight of such an angle per foot run would be nine times that of a bar 1 foot long and 1 inch square. So that having found the number of square

inches in any given section, it is only necessary to consult any table which gives the *sectional areas of bars.* It does not matter whether the bars are round or square, so long as the sectional areas in square inches are given. The same remark applies to other sections besides angles and tees.

Little items in work which are apt to be either overlooked, or under-calculated in estimates, are bolts, screws, studs, and rivets. Very often these are not shown in small scaled detailed drawings, or a few only are indicated by centre lines. Often too in large detail drawings, one is apt to overlook a good number of them unless a minute and careful calculation is made. Perhaps a set-screw is shown in a detail, but the number required may have to be reckoned out by addition or multiplication. Especially is this the case in riveted work. Unless one is very careful it is easy to omit a large number of rivets from a drawing of girder work, involving many different views, and items of detail. The lines of rivets have to be picked out, and their total lengths divided by the pitch. The usual practice is to weigh a rivet of the dimension required, and multiply that by the number of rivets required.

Some useful multipliers suitable for smiths' and plated work are given on p. 415.

It is often desirable to be able to deduce the weight of a piece of work in one material from the weight of a piece of work in another material, as copper from wrought iron, steel from wrought iron, and so on. Tables of comparative weights are given below.

When there is a good deal of work involved in an estimate it is necessary before commencing to go through the details to make a careful list of all the several items.

These may amount to many scores or even hundreds. But if this is not done, some parts are apt to be omitted when going through the details. But besides this, the time spent will not be wholly lost, because the working through the drawings in order to pick out the several items will fix the whole of the job well in the mind, and so facilitate the after calculations.

Further, when setting down the several items, the castings should be reckoned out separately, and the castings in different materials, iron, steel, gun metal, etc., distinct from one another. Then the plates should be tabulated distinct, then angles, tees, joists, shafts, forgings, rivets, bolts, timber, indiarubber, chains, ropes, copper, or other piping. And in each class the dimensions of each several piece should be jotted down, as length, width, and thickness of each piece of plate, with its weight opposite it, the length of each angle, with the width and thickness of its flanges and its weight. When all is done, the results should be tabulated neatly in columns, so that any important omission can be readily detected.

For the weight of round bars in pounds avoirdupois: Square the diameter in inches, multiply by the length in feet and the product by 2·63 for iron, and by 2·67 for steel.

For the weight of square bars in pounds avoirdupois: Multiply the area of the cross section in inches by the length in feet, and the product by 3·36 for iron and by 3·4 for steel.

The weight of a plate of wrought iron 12 in. × 12 in. × 1 in. thick averages about 40 pounds.

Therefore the thickness of any plate a foot square, given in inches and fractions of an inch, × 40 = pounds weight per square foot.

The thickness in eighths of an inch × 5 = pounds per square foot. The thickness in tenths of an inch × 4 = pounds per square foot.

Square feet one inch thick must be multiplied by 40 to obtain the weight in pounds in wrought iron, by 40·8, or, say, 41, to obtain the weight in steel.

When the volume in cubic inches is given to find the weight in pounds, multiply by ·278, or by ·28 for wrought iron, ·283 for steel.

Comparative Weights of Different Bodies

Cast Iron = 1.	Bar Iron = 1.	Steel = 1.	Brass = 1.
Bar Iron = 1·048	Cast Iron = ·953	Cast Iron = ·925	Cast Iron = ·867
Steel . . = 1·076	Steel . . = 1·026	Bar Iron = ·973	Bar Iron = ·909
Brass . = 1·153	Brass . = 1·1	Brass . = 1·07	Steel . . = ·933
Copper . = 1·213	Copper . = 1·151	Copper . = 1·128	Copper . = 1·05
Gun Metal = 1·208	Gun Metal = 1·150	Gun Metal = 1·121	Gun Metal = 1·046
Lead . . = 1·564	Lead . . = 1·5	Lead . . = 1·453	Lead . . = 1·357

Copper = 1.	Gun Metal = 1.	Lead = 1.	Yellow Pine = 1.
Cast Iron = ·83	Cast Iron = ·8288	Cast Iron = ·64	Cast Iron = 16·0
Bar Iron = ·866	Bar Iron = ·8687	Bar Iron = ·67	Steel . . = 17·0
Steel . . = ·89	Steel . = ·8917	Steel . . = ·688	Brass . . = 18·8
Brass . = ·95	Brass . = ·9558	Brass . . = ·737	Gun Metal = 19·0
Gun Metal = ·99	Copper . = 1·0004	Copper . = ·774	Copper . = 19·3
Lead . . = 1·29	Lead . = 1·292	Gun Metal = ·778	Lead . . = 24·0

WEIGHT OF IRON, STEEL AND COPPER PLATES, 12 in. × 12 in., from $\frac{1}{4}$ in. to $1\frac{1}{2}$ in. thick

Thickness.	Sectional Area.	Wrought Iron Lb.	Steel. Lb.	Copper. Lb.
$\frac{1}{4}$	3·00	10·0	10·2	11·5
$\frac{5}{16}$	3·75	12·5	12·75	14·37
$\frac{3}{8}$	4·50	15·0	15·3	17·24
$\frac{7}{16}$	5·20	17·5	17·85	20·12
$\frac{1}{2}$	6·00	20·0	20·4	23·0
$\frac{9}{16}$	6·75	22·5	22·95	25·87
$\frac{5}{8}$	7·50	25·0	25·5	28·74
$\frac{11}{16}$	8·25	27·5	28·05	31·62
$\frac{3}{4}$	9·00	30·0	30·6	34·48
$\frac{13}{16}$	9·75	32·5	33·15	37·37
$\frac{7}{8}$	10·50	35·0	35·7	40·24
$\frac{15}{16}$	11·25	37·5	38·25	43·12
1	12·00	40·0	40·8	46·0
$1\frac{1}{16}$	12·75	42·5	43·35	48·87
$1\frac{1}{8}$	13·50	45·0	45·90	51·75
$1\frac{3}{16}$	14·25	47·5	48·45	54·62
$1\frac{1}{4}$	15·0	50·0	51·0	57·48
$1\frac{5}{16}$	15·75	52·5	53·55	60·37
$1\frac{3}{8}$	16·5	55·0	56·10	63·24
$1\frac{7}{16}$	17·25	57·5	58·65	66·12
$1\frac{1}{2}$	18·0	60·0	61·2	68·96

THE WHITWORTH SCHOLARSHIPS

The four Whitworth Scholarships are each of the value of £125 a year, and are tenable for three years. Competition is open to any of His Majesty's subjects, of

sound bodily constitution, whether of the United Kingdom or the Colonies. The candidate must be under 26 years of age on the 1st of May of the year in which he competes. The examination is divided into theoretical subjects and practical workmanship. The subjects of the theoretical examinations are—

Practical Plane and Solid Geometry, Machine Construction and Drawing, Building Construction and Drawing, Naval Architecture, Mathematics, Theoretical Mechanics, Solids and Fluids, Applied Mechanics, Sound, Light and Heat, Magnetism and Electricity, Inorganic Chemistry, Theoretical and Practical Metallurgy, Theoretical and Practical Steam, and Freehand Drawing.

Candidates must have been engaged in handicraft for at least three years, and have been at work at the vice and lathe, or the forge, or the bench, for at least six consecutive months in each of those years. They must have spent at least twelve months at the vice and the lathe, not less than three months having been spent at the vice, and three months at the lathe.

The Whitworth Exhibitions are of the value of £50 only, and tenable for but one year. There are about thirty of these competed for in a year. The rules of the competition are the same for both Scholarships and Exhibitions. Some of the subjects noted above are optional in the case of candidates engaged in different handicrafts. Thus, engineers need not take up Building Construction and Naval Architecture; and those engaged in the building trades need not qualify in Machine Construction and Drawing, and Naval Architecture. As in the Royal Exhibitions of the Department of Science and Art, the awards are made according to the number of marks gained, full particulars of which can be obtained in the official

prospectus. No candidate can obtain an Exhibition or Scholarship who has not passed in—

(*a*) The Advanced Stage or Honours of Practical Plane and Solid Geometry. (*b*) The Second or a Higher Stage, or the Honours of those stages, of Mathematics. (*c*) The Elementary or Higher Stage of either section of Theoretical Mechanics. (*d*) Freehand Drawing of Ornament, Elementary Stage. If a candidate has once *qualified* in the subjects above mentioned, it will not be necessary for him to be examined or to pass again in those subjects, but no *marks* can be counted for a success obtained in a previous year. Moreover, no candidate can obtain an Exhibition or Scholarship who has not attained sufficient handicraft power. And if it be thought necessary by the Department, this may be tested by requiring him to make two Whitworth screw bolts, 1 in. in diameter and 4 in. to 6 in. long, with hexagonal heads and nuts, alike within ·001 in.

Any person wishing to compete for a Whitworth Scholarship or Exhibition, can obtain a Form (No. 90) giving the dates, &c., of the examinations held under the superintendence of Local Committees about the month of May, on application to the Secretary, Board of Education, London, S.W., at the beginning of March. Certain forms, obtainable from the Department, have then to be filled up and returned; No. 330 T. before the 15th April; No. 400 T., and No. 396 T. before the 15th June. They may be obtained from the Board about a fortnight before the times fixed for their return. The first is a proposal form; the second states the subjects and stages in which the candidate came up for examination; the third, gives information as to experience in practical work; and the latter has to be certified to by the employers

of the candidate, or, failing these, by some person of position who can speak to its correctness. Examinations are held at all considerable industrial centres, but candidates who do not reside near any place where arrangements have been made for examination, may be examined at the South Kensington Museum on payment of certain fees which are stated in the time table of examinations (Form No. 90). They should apply before the 20th March.

No candidate can obtain a Whitworth Scholarship twice, and no Whitworth scholar is eligible to compete for a Whitworth Exhibition. No person can take a Whitworth Exhibition twice; but a candidate who has obtained an Exhibition, may, if otherwise eligible, compete for a Scholarship in a subsequent year.

When a Scholarship has been gained the scholar must propose for the approval of the Board of Education the manner in which he wishes to spend the tenure of his Scholarship, and it must be clearly understood that the tenure is subject to the condition that the scholar spends his time in pursuing the course of work or study which is approved of by the Board.

The course should be theoretical and practical, so as to improve both his mental and physical training. The holder of a Scholarship will be required to devote his time while holding the Scholarship to the prosecution of his education as a mechanical engineer. The payments are made half-yearly, on the receipt of satisfactory reports from the scholar, supported, if it be required by the Board, by satisfactory evidence of progress from the place of study or workshop he has attended; and the Scholarship may be withdrawn if satisfactory progress has not been made in the approved course of work or study. The reports should be made on the 1st May and 1st November in each year.

No scholar will be permitted to take any place of profit, or continue in any business he may be engaged in when he obtains his Scholarship, except under very exceptional circumstances, and with the special sanction of the Board of Education. He must devote himself to completing his education at the place or places of study or work approved by the Board. Exhibitioners, however, will be permitted to hold posts of profit or emolument while holding their Exhibitions. The holder of an Exhibition, though required to submit for the approval of the Board a scheme of work or study for the year of holding his Exhibition, will be permitted considerable latitude in framing this scheme, which should be both theoretical and practical. On the approval of the scheme, half the Exhibition money will be paid; the other half on receipt of a satisfactory report at the end of the Exhibition year, terminating on the 1st May.

Travelling expenses of those candidates who are required to attend for practical examination will be paid. Third-class fare will be allowed, and 7*s.* 6*d.* per night as long as they are required to be absent from their homes.

Complete syllabuses of the subjects of competition for the Whitworth Scholarships and Exhibitions can be obtained in the prospectus of the Whitworth Scholarships, from the Board of Education, London, S.W.

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